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THE TREATMENT OF BURN SHOCK WITH CONTINUOUS HYPODERMOCLYSIS OF PHYSIOLOGICAL SALINE SOLUTION INTO THE BURNED AREA

An Experimental Study

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THE body reacts in a similar manner to trauma of all kinds. Therefore this article may properly be said to deal with a physiological method of combatting extensive external traumatic lesions, a method which may be applied in the treatment of crushing, contused, and chemical injuries as well as of burns.

CAUSES OF BURN SHOCK AND TOXEMIA

The causes of burn shock have received extensive investigation and although not fully understood the sequence of events seems to be as follows: As a result of the injury there is increased permeability of the capillary endothelium permitting the escape of plasma into the burned area (2). This leads to hemoconcentration which in turn causes a stagnant anoxemia to occur (Fig. 1). Intercellular fluid is drawn into the blood stream and is in turn lost into the burned area. As anoxemia increases, tissue cells are damaged, especially in the brain, heart, and blood vessels. Capillaries begin to lose fluid in many areas. In the experimental animal this is particularly noticeable in the lungs.

The rôle of hypothetical toxins in this process has not been determined. However, our observations compel us to recognize the possibility of the assimilation of abnormal metabolic products. Colloids and crystalloids are absorbed very early after a burn and this absorption is continued throughout its acute phase.

Many patients die from burn shock within 36 to 48 hours. If they survive this period death is thought to be due to burn toxemia. It is probably caused by a combination of such factors as dehydration, hemoconcentration, anoxemia, infection, and absorption of toxins, resulting in damage to the liver, kidneys, adrenals, lungs, and brain. Such patients usually have high fever, anuria, and pulmonary edema.

PRESENT TREATMENT OF BURNS

We have previously stated that the treatment of burn shock is based upon two important factors. First, every effort should be made to prevent the loss of plasma and electro-

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lytes. For this we urged firm pressure bandages when the burn involved the extremities (1). We found that this was not practical for the torso or face. Second, the lost plasma must be replaced (5). Koch advocates that the burned area be cleansed with soap and water under aseptic conditions, blisters should be opened, and a sterile pressure bandage should be applied. The use of the sulfonamides internally and ample oxygen by inhalation have also contributed to the reduced mortality from burns.

It is evident that any treatment of extensive burns must take cognizance of the following important integrants: (1) curtailment of the loss of plasma at the site of the burn no matter how extensive this may be; (2) restoration of lost plasma and electrolytes; (3) facilitation of dilution and excretion of toxins; (4) control of body temperature. If these primary disturbances can be modified, secondary effects such as hemoconcentration, anoxemia, hypochloremia, hepatic and renal insufficiency may be averted to a great extent.

PURPOSE OF EXPERIMENTS AND METHODS EMPLOYED

Our chief purpose was to lessen the loss of plasma and electrolytes and to facilitate their reabsorption. In an attempt to accomplish this we introduced physiological saline solution subcutaneously at a pressure exceeding capillary hydrostatic pressure, namely 40 millimeters of mercury.

Healthy dogs were anesthetized with sodium amytal intravenously—40 milligrams per kilogram of body weight. The animals were weighed, the hair was clipped from the forelegs down, blood was drawn for hematocrit, hemoglobin, serum chloride and serum protein, uric acid creatinine, and nonprotein nitrogen determinations. Body temperature, blood pressure, pulse, and respiratory rates were noted.

The animals were then dipped into a large tub of boiling water—99 degrees C.—up to the forelegs for 20 to 40 seconds. Thirty-two seconds was found to produce a uniformly severe burn. A catheter was anchored in the urinary bladder. The carotid artery was cannulated, flushed with citrate solution, and attached to a manometer and recording drum.

One cubic centimeter of phenolsulfonphthalein solution was injected subcutaneously on one side of the lower thoracic wall and 1 cubic centimeter of India ink was introduced subcutaneously on the other side. At the same time 0.85 per cent saline solution was given by hypodermoclysis. The solution was placed in an open flask and connected with three tubes. One of these was attached to a mercury manometer so that the pressure could be maintained at 40 millimeters of mercury; the other two were equipped with hypodermic needles and were variously inserted in the thoracic abdominal and thigh regions. In this manner amounts up to 12 per cent of the body weight were given.

Some animals received the salt solution without manometric guidance. That is, the solution was injected until the tissues were distended. The needles were allowed to remain in place and the tubes were clamped when the skin seemed tense. As absorption proceeded more solution was injected. In the dog the skin is loosely attached due to the well developed panniculus carnosus (platysma in man). Fluid introduced anywhere subcutaneously permits diffusion throughout the body. However, absorption is more rapid in the thoracic area. Results were the same in both groups of animals.

The urine was collected and tested for phenolsulfonphthalein content from time to time. Also at intervals blood was drawn for studies previously enumerated. It required extreme care to prevent hemolysis of the samples.

Each group of experiments was controlled by a burned, untreated animal. Autopsies were done at the conclusion of each experiment. Microsections were made from the skin and subcutaneous tissue, lymph nodes, lungs, spleen, liver, kidneys, and adrenals.

RESULTS OF EXPERIMENTS

Survival time. The survival time varied with the length of time that the animal was burned. Burns lasting 40 seconds resulted in death of the controls in 13 minutes; treated animals lived 1 hour and 22 minutes. Dogs burned for 20 seconds lived 18 hours if untreated and 30 hours if treated. Most animals were dipped into the boiling water for 32 seconds. The

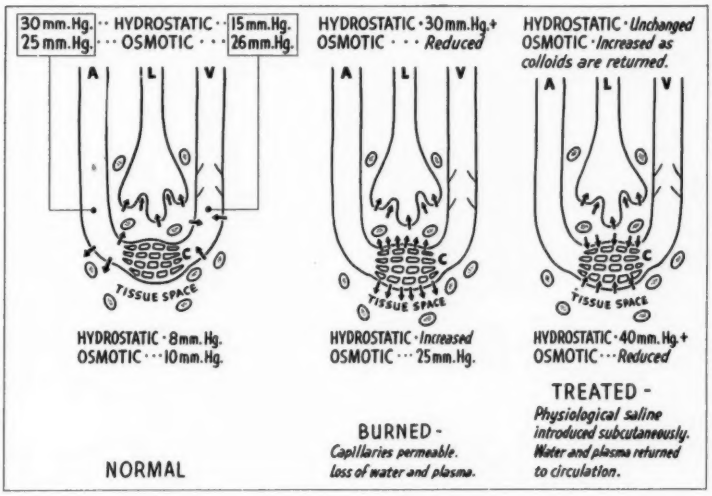

Fig. 1. Mechanisms involved in the interchange of body fluids. a, Normal, Starling's hypothesis assumes that blood in the capillaries is under two forces: a hydrostatic pressure which tends to force fluid outward and an osmotic pressure which tends to attract fluid into the capillary. These are balanced somewhat by similar pressures in the surrounding tissues. The effective hydrostatic pressure is greater on the arterial side of the capillary, *A*, and therefore there will be a flow of crystalloids and solutes outward into the tissue spaces. On the venous side, *V*, the effective osmotic pressure is greater and fluid is attracted into the capillary. Colloids are returned to the blood stream by the lymphatics, *L*, which behave as a semipermeable membrane. b, Burned, the capillary wall plays an important rôle in this mechanism because it is normally impermeable to colloids which are chiefly proteins (albumin, globulin, fibrinogen, especially the former) but it is permeable to crystalloids. Anything, therefore, injuring capillary endothelium would immediately disarrange the normal interplay of these forces. c, Treated, the hydrostatic pressure in the tissue spaces is increased and the osmotic pressure is decreased. The loss of crystalloids and colloids is minimized, and their absorption into the capillaries and lymphatics is facilitated. (Redrawn from Berman's *Synopsis of the Principles of Surgery*. C. V. Mosby Co., 1940.

average survival time for the controls was 9 hours and 24 minutes; for treated animals 14 hours and 30 minutes—an average of about 35 per cent longer.

General condition. Treated animals remained in better condition and were more stable than the controls. This conclusion is based upon the regularity of respiration, heart rate, blood pressure, and temperature as depicted in the graphs and as discussed in subsequent paragraphs. Salivation occurred in all animals immediately after the burn. Soon the mucous membrane of the mouth and tongue was dry in the controls but remained moist in the treated dogs.

Pulmonary edema. A constant finding was the presence of pulmonary edema in all control animals. This could be easily detected by the loud râles which were audible without the use of the stethoscope. It becomes apparent about 1 hour after the burn and becomes progressively worse. In 1 control animal a tracheotomy was done and large amounts of thick ropy fluid were aspirated. In the treated dog tracheotomy permitted the aspiration of only normal amounts of secretion. Autopsy studies confirmed the presence of edema.

The mechanisms effective in the cause of pulmonary transudates and exudates in the lung have been recently described by Drinker. The former term is used to imply the movement of fluids through normal capillary endothelium; the latter through more permeable or abnormal capillary walls. Since the normal

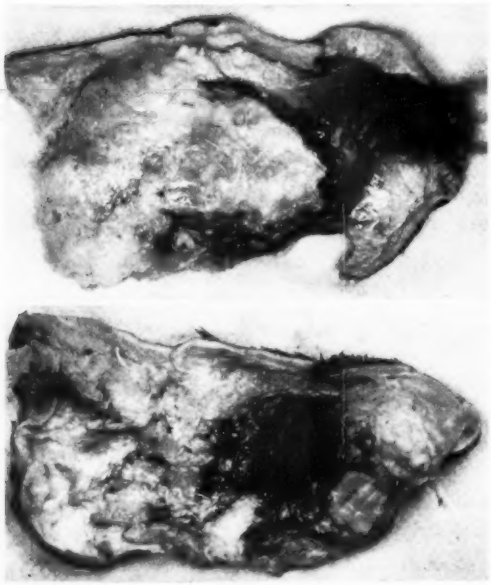

Fig. 2. Postmortem photograph of subcutaneous area in which 1 cubic centimeter of India ink was injected. a, Above, dog treated with hypodermoclysis of physiological saline. b, Control.

osmotic pressure prevails in pulmonary capillaries and since the hydrostatic pressure is extremely low (about 10 mm. of mercury) and, lastly, since the intrathoracic pressure is slightly negative (−5 to −10 mm. of mercury), the flow of solutes is entirely into the lumen of the capillary and therefore the lung is dry. Furthermore, as in other tissues, colloid particles are returned by the lymphatics and in the lung these are very amply present. Therefore, large quantities of fluid may be lost into the lung, either as transudates or exudates, or fluid may enter from some external source, but it is usually quickly returned to the blood stream through the blood capillaries or through the lymphatics.

The cause of pulmonary edema in our control dogs may have been due to the early loss of water producing dehydration and hemoconcentration. These conditions in turn lead to stagnant anoxemia causing hyperpnea. In addition, the high fever probably caused more fluid to reach the lungs for evaporation so that the temperature would be reduced. The pulmonary capillaries became more permeable due to dilation and anoxemia. These factors together with the increased rate and amplitude of respiration caused more fluid to leave the capillaries, at first by transudation and later by exudation.

Absorption of colloids and crystalloids from the burned area. We were interested in knowing whether or not the injected subcutaneous saline solution would be absorbed. Also whether colloids lost from the permeable capillaries would be returned to the blood stream. To prove this we injected phenolsulfonphthalein solution 1 cubic centimeter on one side of the burned area and 1 cubic centimeter of India ink on the other at the same time that the saline solution was introduced. The latter varied in amounts from 800 to 2400 cubic centimeters. The average was 1600 cubic centimeters or 12 per cent of the body weight. Injection of fluid anywhere under the skin quickly diffused over the entire body within ½ hour. The good effects of this treatment were not so apparent when the solution was injected 2 hours or more after the burn as evidenced by anuria in some of these animals. Best results were obtained when the treatment was used immediately.

In the treated animals, phenolsulfonphthalein was detected in the alkalinized urine within an average of 11 minutes after its injection. The controls had no urinary output but aspiration of a few drops of urine in the urinary bladder of some controls at postmortem did reveal phenolsulfonphthalein in the urine. Examination of the site of injection showed the solution to be present as a large bleb in controls; it was almost completely absorbed in the treated animals.

Fluid injected in the thoracic wall was much more quickly absorbed than in the abdominal area or the subcutaneous tissue over the extremities. In some animals this absorption was complete within 1 hour.

Injection of India ink revealed comparable findings. In the treated animals it was found in the anatomical lymph nodes, the lungs, liver, and spleen. In the controls small amounts were detected sporadically in these organs. However, most of it remained as a large bleb at the site of injection (Fig. 2). We concluded

from these and subsequent findings that subcutaneous isotonic salt solution at 40 millimeters of mercury pressure not only decreased the outward flow of plasma protein, as revealed by the discussions which follow, but in addition facilitated the absorption of crystalloids and colloids as well, the latter by the lymphatics, after the injured tissues' increased demand for salt had been satisfied.

Body temperature. There was a uniform rise in temperature of about 1 degree F. in the control immediately after the burn, which remained constant for about 3 hours. Then a rapid rise occurred which became progressively higher (Fig. 3). The animals died with temperatures averaging 105 degrees F. The treated animals behaved differently. Body temperatures began to fall within 1 to 2 hours after the burn, reaching 97 degrees after 5 hours and remaining at this level for about 2 hours. After this the temperatures remained normal.

The initial rise in the controls was probably not due to the absorption of hypothetical toxins, or dehydration because the time interval was too short. We believed that it was due to a condition allied to heat stroke which was controlled in the treated animals. It was our opinion that this method of treatment could be used in heat stroke and shock. The terminal hyperpyrexia in controls was probably caused by a combination of factors such as dehydration, anuria, pulmonary edema, and absorption of toxins. These were corrected in great measure by the hypodermoclysis in the treated animals which might also have been the means of dilution and elimination of toxins.

Pulse rate. The pulse rate in the treated animals was more uniform and in general slower than in the controls. Dogs with pulse rates of 140 to 150 immediately after the burn, fell to 100 within 2 hours after treatment, then gradually increased. Controls showed a rise in pulse rate which was sustained for about 3 hours. After this the pulse became very weak by the rate decreased rapidly. This was thought to be due to incomplete cardiac contractions (Fig. 3).

Respiration. Untreated animals had irregular deep respiration with varying periods of apnea. During the first 6 hours this irregularity ranged between 10 and 28 per minute.

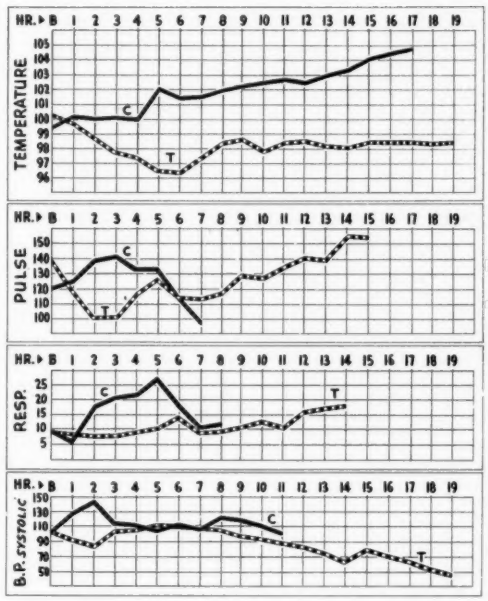

Fig. 3. Composite graphs of body temperature, pulse, respiration, and blood pressure. Hourly readings were averaged for all treated animals, *T*, and controls, *C*.

After this period respirations dropped to an average of 9, but were not shallow. This rate increased until death. Treated animals also had varying rates and amplitudes which were more or less constant, increasing progressively until the death of the animals. Averages were difficult to obtain because of minute variations. However, the composite chart reveals in a general way the behavior of the treated and untreated dogs (Fig. 3).

Blood pressure. Control dogs showed a rise in blood pressure immediately after the burn. Within 2 hours the average systolic pressure had increased 40 millimeters of mercury. This remained only 20 to 30 minutes then rapidly declined. Treated animals had a slight fall in pressure immediately after treatment. Within 2 hours after the burn it had fallen on an average of 20 millimeters of mercury. This level remained for only 20 to 30 minutes then regained its previous level which was sustained for 4 to 6 hours. After this there was a gradual fall (Fig. 3). The findings in our controls agree with those of Olson and Necheles,

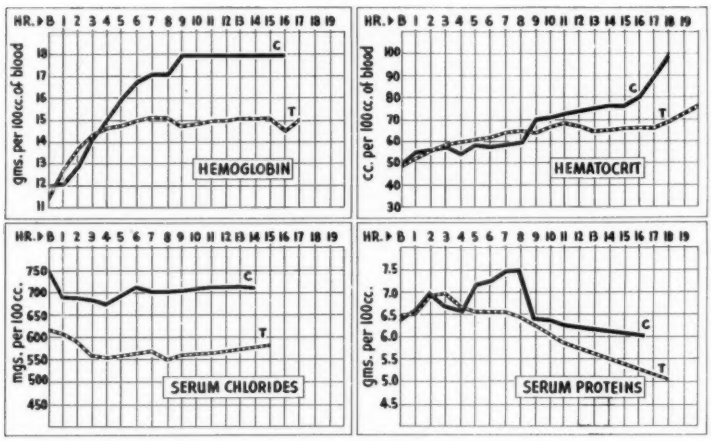
HR. ▸ B 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
gms. per 100cc. of blood
C
T
HEMOGLOBIN
cc. per 100cc. of blood
HEMATOCRIT
mgs. per 100 cc.
SERUM CHLORIDES
gms. per 100cc.
SERUM PROTEINS

Fig. 4. Composite graphs of hemoglobin, hematocrit, serum chloride, and serum protein. Blood samples were drawn at various intervals throughout the experiments. Figures for comparable time intervals were then averaged. *C*, Control; *T*, treated dogs.

who thought the pressor effects due to stimulation of the posterior pituitary.

The behavior of the respiration, pulse, blood pressure, and temperature is difficult to correlate especially in the controls which behaved in an erratic manner. However, in treated animals the entire picture was one of stabilization near normal levels.

Urinary output. Immediately after the burn all dogs passed 8 to 10 cubic centimeters of urine. Anuria was present in practically all of the controls as the experiment progressed. The average amount of urine put out by the controls was 17.3 cubic centimeters and all of this was early in the experiment. Treated animals continued to excrete urine throughout the experiment if the salt solution was given immediately after the burn. The average output was 66 cubic centimeters. If 1 to 2 hours was allowed to elapse before treatment only a few drops of urine were excreted. One group of treated animals burned for 40 seconds died within 2 hours. Only a few drops of bloody urine were excreted and the kidney pelves were filled with blood. Changes in the kidneys take place rapidly and treatment to be effective must be instituted early. Corcoran and co-workers have recently explained some of the kidney behavior by a vasoconstriction of the efferent glomerulus arteriole.

Examination of the urine in controls was impossible except early in the experiment. At this time there was a faint trace of phenolsulfonphthalein, some albumin, some blood. Treated animals began to excrete phenolsulfonphthalein within 10 minutes after its injection. Sugar was negative, albumin averaged 0.864 grams per cent, there was no bilirubin, some oxidized urobilinogen, and on microscopic examination some red blood cells were found.

Body weight. At the conclusion of our experiments, before postmortem examinations were done, the animals were weighed. Those treated with physiological saline solution gained on an average of 1.33 kilograms or 2.93 pounds. This is slightly less than the average amount of fluid injected. The difference was no doubt due to fluid loss by the lungs and kidneys. Control animals uniformly lost weight. The average amount was 0.313 kilogram which was due to loss of fluid chiefly by the lungs for this is the dominant method of evaporation in the dog.

Blood studies. (*a*) *Hematocrit.* All animals showed a rise in hematocrit readings. This began immediately after the burn and continued throughout the experiment. Controls show a much greater average rise (up to 100%) than do the treated animals which rose to 76 per cent (Fig. 4).

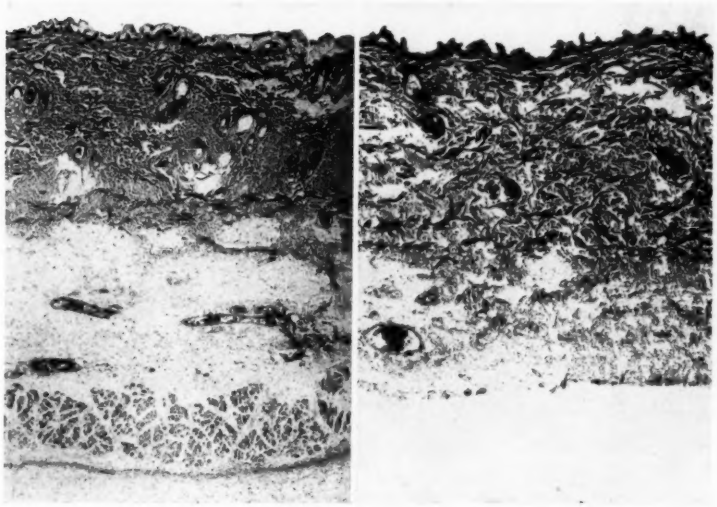

Fig. 5. Photomicrographs of skin and subcutaneous tissue showing second and third degree burns. Note the space caused by physiological saline in the subcutaneous area of the treated animal. a, left, Treated dog; b, control.

(*b*) The *hemoglobin* determinations paralleled the hematocrit findings and were even more striking. Controls showed an average rise from 12 to 18 grams. This elevation occurred abruptly 2 hours after the burn. Treated dogs behaved in a similar manner, but the rise was up to 15 grams and remained at this level throughout the experiment (Fig. 4).

(*c*) *Serum protein.* There is an initial slight rise in serum protein in all animals. Four hours after the burn control animals show a rapid rise from 6.6 to 7.5 grams which is sustained for about 3 hours; then there is an abrupt fall which continues throughout the experiment. Treated animals show a slight but progressive fall beginning 3 hours after the burn (Fig. 4). This behavior we believe is due to the early loss of water which in the control continues for about 8 hours then there is a shift of fluids from the tissues to the blood stream. Also capillaries begin to lose protein in large amounts at this time. Treated animals have their water restored from the start and, except for the 2 hour lag at the beginning of the experiment, protein is gradually lost although restoration is going on. Of course the protein level will have become lower as a result of hemodilution.

(*d*) *Serum chloride.* Immediately after a burn, controls show a quick fall within the first hour amounting to an average of 75 to 100 milligrams. A slight rise occurs at 6 hours for a short time, then there is a fall with no variation. Treated animals show only a slight fall which is progressive for about 3 hours then there is a slight but constant rise. By referring to Figure 4 it will be noted that the early fall in chlorides corresponds to the rise in serum protein. In the controls the secondary rise in protein is accompanied by a slight rise in chlorides. Since volumetric studies were not made total changes cannot be recorded. However, these figures seem to indicate first a loss of water and electrolytes, then migration of crystalloids into the blood stream for osmotic reasons; then a loss of plasma with continued migration of water and protein from tissue spaces into the blood. Treated animals do not show this large loss of electrolytes or proteins, although the trends are the same.

(*e*) *Azotemia.* All animals showed a rise in nonprotein nitrogen, uric acid, and creatinine levels. In most instances there was a more rapid and greater rise in the controls than in the treated animals. Nonprotein nitrogen in controls rose from an average of 25 to 74 milli-

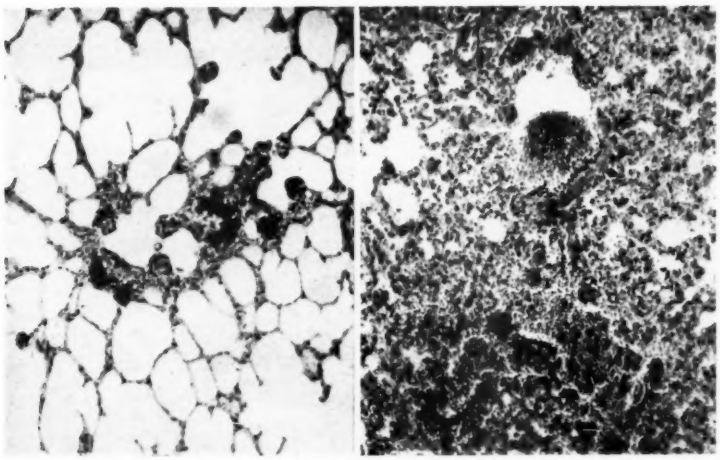

Fig. 6. Photomicrographs of the lungs in a, left, treated, and b, control, dogs. There are congestion and pulmonary edema in the latter. India ink is abundantly scattered throughout the lungs of the treated animal. Note the thickened alveolar walls. On high power this is seen to be due to great hyperemia. There is some bloody exudate in the alveoli and bronchioles.

grams; treated animals from 30 to 59 milligrams. Uric acid in controls increased from 3 to 6.2 milligrams; in treated dogs from 3 to 4 milligrams. Creatinine in controls averaged 1.26 milligrams at the beginning of the experiment and 1.90 at its end. Treated dogs showed a rise from 1.20 to 1.76 milligrams.

Splenectomized dogs. Control and treated splenectomized dogs behaved very much as the other animals with one outstanding exception; hemoglobin and hematocrit readings were much lower. This observation together with the contracted spleens found at postmortem in other animals, would lend support to the belief that at least some hemoconcentration after a burn is due to the large volume of blood released from the splenic reservoir.

Postmortem studies. It was our purpose to find the extent of India ink absorption and to record any notable changes encountered. Detailed microscopic morphological studies are not included in this study. The animals were allowed to die of their burns. The skin showed second and third degree burns (Fig. 5). Treated animals showed a separation of the skin from the fascia due to the injected fluid. Lymph nodes in control and treated dogs contained India ink, much more was found in the latter. The pleural cavities did not contain free fluid. The lungs of control dogs were wet and showed pulmonary edema. Treated dogs did not exhibit this. India ink particles were found in both but again there was much more in treated animals (Fig. 6.) There was no free fluid in the abdominal cavity. Intestines were congested in controls but were pale in treated dogs. One control dog was found to have a duodenal (Curling's) ulcer. The spleens were contracted in all animals. Spleens in controls had less India ink particles than in treated dogs. Kidneys were hyperemic and congested in controls. Some tubules were filled with blood. Changes were not constant in either group. The livers of controls showed areas of focal necrosis, some cloudy swelling and a small amount of India ink. Treated dogs had much more India ink and more nearly normal livers. Adrenals showed no significant differences.

We concluded from our findings that there was a widespread dissemination of India ink in treated animals which was not as apparent in controls. This would further prove that lost protein is reabsorbed and sent to all of the vital organs of the body. Pathological changes were found in both groups but were less apparent in treated dogs.

RECAPITULATION

Our studies lead us to believe that there is first a loss of water then plasma into the burned area. This continues until the tissue space pressure equals the hydrostatic pressure within the capillaries. Then reabsorption begins but in a reverse manner. That is, colloids are returned first by the lymphatics which behave as a semipermeable membrane. Then crystalloids are absorbed by the capillaries.

The loss of plasma occurs earlier in animals more severely burned; therefore, early treatment is imperative.

Treatment by hypodermoclysis of isotonic salt solution seems to decrease the amount of water and plasma lost and it facilitates the absorption of both. Prinzmetal and associates have observed that the intraperitoneal administration of a 0.9 per cent solution of sodium chloride in large amounts (5 to 10% of the body weight) to mice and rats after scalding significantly decreases mortality. Rosenthal observed this to be due to the sodium ion and found that isotonic solution of sodium salt given orally was more effective than the same solution given intravenously. These findings lend strong support to our observations. Perhaps water given by mouth to burned patients would be retained in the blood stream if sufficient sodium chloride was administered at the same time.

Human skin is not as loosely attached to the subcutaneous tissue as is that of the dog and therefore multiple injections would be necessary but much less solution would be needed to produce an intercellular hydrostatic pressure above that of effective capillary pressure. This method has not been employed in the human. However, its feasibility is apparent and could be used in addition to intravenous plasma and other methods of treatment. Certainly it would decrease the amount of plasma which has recently been found to be necessary in treating extensive burns. It is indeed an autotransfusion of lost colloids and crystalloids; and in addition a method for supplying quickly the great demand for salt by injured tissues.

CONCLUSIONS

Isotonic sodium chloride solution injected hypodermically into the burned area in experimental animals curtails the loss of plasma and electrolytes, makes possible the dilution and excretion of hypothetical toxins, controls body temperature, prevents pulmonary edema and anuria. As a result of these effects survival time is considerably increased in the treated animals.

Since submitting this article for publication Fox (14) has described the treatment of burned patients with the oral administration of sodium lactate. By using radioactive sodium he has demonstrated an enormous deposit of this element in the traumatized tissues of experimental animals.

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THE LOCAL SKIN LESION IN EXPERIMENTAL BURNS AND ITS RELATION TO SYSTEMIC MANIFESTATIONS

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THE necrosis of the skin in clinical burns is generally classified only according to its depth without recognition that necrosis may assume different forms. Yet it has long been known that a dry, hard necrosis of the skin is apt to be produced by flame (2). Early in our experimental studies it seemed clear that the damage to the skin varied not so much in depth as in intensity, one of the first observations being the existence of either a dry necrosis or a wet necrosis of the skin, dependent upon different types of burn stimuli. We had previously noted the same two types of necrosis in many clinical burns. For these reasons, we decided to study more carefully the nature of the burn lesion produced by varying thermal injuries.

METHODS

Varying types of thermal stimuli occur in actual warfare or in civilian accidents. In most of them the individual is either burned by hot water or oil, which comes in direct contact with the skin, or by the actual flame, usually when his clothes catch fire. To this must be added a relatively new type of burn called the flash burn, which is a very intense but momentary thermal stimulus producing, however, a superficial injury usually involving necrosis of tissue.

In the setting up of methods for experimental burns a number of procedures are available, which may be listed as follows:

The actual flame. This method is usually carried out with a Bunsen flame. The degree of injury is hard to control, and as we observed in our earlier experiments the lesion produced is quite variable. Because this procedure, moreover, scarcely imitates the conditions observed clinically we soon discarded this technique. On the other hand, a more accurate method of studying the effect of flame under conditions approximating that observed clinically is achieved by igniting a measured amount of gasoline poured over the skin. Thus the degree and duration of the flame can be accurately measured. This was one of the techniques we used in the present study.

The dipping technique. This method is capable of accurate control and requires simply the immersion of a measured portion of the body surface into a liquid at any desired temperature for any length of time. Moreover, it imitates rather well what happens clinically whenever a person is burned by hot water or oil, and is the one we used in our original experiments as already described (1). It should be mentioned, however, that very short lasting immersion probably approaches more closely the conditions observed clinically, inasmuch as it is quite unlikely that in human burns the hot water or oil will remain in contact with the skin more than a few seconds.

The application of a heated object. This method permits the study of small isolated areas but has an important disadvantage in that pressure is applied as well as heat, a fact which increases the degree of the injury. Moreover, such a burn stimulus is seen clinically only over relatively small areas which present no great problem in treatment. We therefore discarded this particular method of studying thermal injury.

Radiant heat. The actual cautery, when applied to the skin, inevitably involves a certain amount of pressure which, as mentioned, introduces an additional and uncontrollable factor. However, if the tip of the cautery is held a few millimeters from the surface of the skin, one can produce a burn by radiation uninfluenced by the effect of pressure, and which can be controlled fairly well, although not as accurately as the immersion or the flame technique described. Another way of applying radiant heat is the use of magnifying

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lenses to focus a spot of concentrated light on the skin for varying intervals of time.

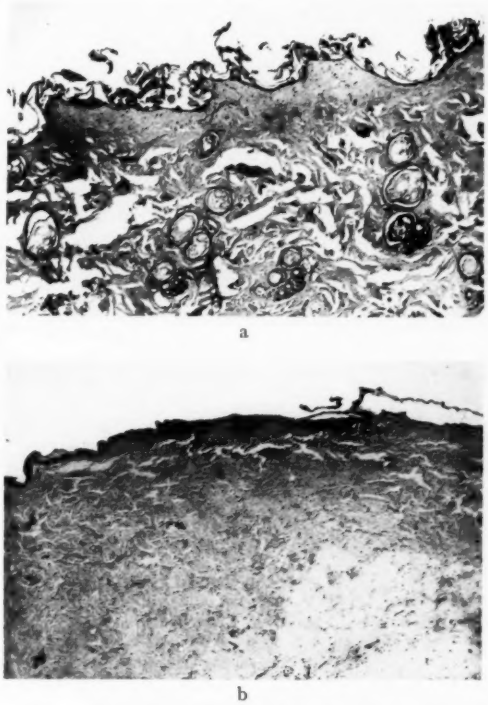
EXPERIMENTAL FINDINGS

In all about 25 animals were used in this study. All observations were made on deeply anesthetized dogs whose hair had been removed previously.

By using the technique described, the types of skin lesions observed can easily be classified into three groups as follows:

1. Inflammatory reaction with edema but no necrosis. As mentioned in our previous communication (1), immersion of the deeply anesthetized dog for 5 seconds in water at 80 degrees C. is followed by an inflammatory reaction including edema without necrosis or infection. If the animal survives, this edema subsides after 24 hours or more and leaves little or no permanent effects in the skin. Inflammatory edema may also be produced with higher temperatures provided the period of exposure is momentary. For example, heated mineral oil up to 180 degrees C. dropped on the skin produces an edema which subsides. If a large volume of such a hot liquid is poured upon the skin over a period of 1 or more seconds, the area covered by the oil will be similarly edematous, although in the center necrosis will occur. With radiant heat as produced, for example, by an actual cautery which is held a few millimeters from the skin but not in contact with it, edema will result if the exposure is momentary, but any exposure beyond 1 or 2 seconds will result in definite necrosis. The actual flame also produces edema provided it is of short duration, e.g., if a drop of gasoline is placed upon the skin and set fire, the resulting lesion will consist of edema only. It is only when the flame burns for more than 1 or 2 seconds that actual necrosis occurs.

2. Wet necrosis of the skin. On immersion of deeply anesthetized dogs in water at 100 degrees C. for periods beyond 2 and up to 10 or 15 seconds, a necrosis of the skin will be produced which manifests itself within a day or two as a swollen, moist, necrotic area which becomes infected rapidly. This lesion is particularly prone to occur on the inner surface of the thighs rather than the outer surface,



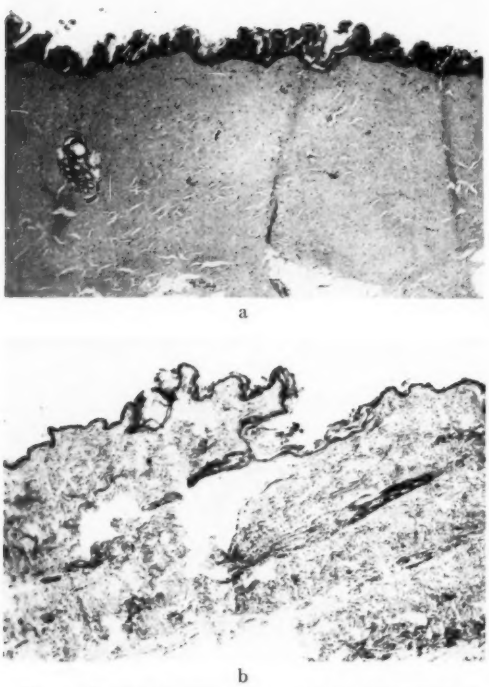
a

b

Fig. 1. Photomicrographs of skin subjected to thermal injury by immersion in water at 100 degrees. Specimens removed at the end of 24 hours, a, from the inside of the left leg which had been exposed to a thermal stimulus for 20 seconds. Note the intact epithelial layer and the swelling of the dermis with little evidence of inflammation. In b, removed from the inside of the right leg, the exposure was 10 seconds. Note the disappearance of the epithelial layer, the evidence of infection as shown by inflammatory cells and the extensive edema. × 34

although there is considerable variation from animal to animal. Of special interest was the fact that hemorrhage of the adrenal was observed when this type of lesion was produced and if survival for 24 hours or more occurred, a finding which was never observed when edema alone was produced. Microscopic study of the skin lesions showed disappearance of the epithelium, edema, infiltration of leucocytes and other signs associated with infection. (Figs. 1b, 2b, and 3b).

3. Dry necrosis of the skin. In deeply anesthetized dogs immersed in water at 100 degrees C. for 20 seconds or more, a necrosis of the skin occurred but it was of the dry type.



a

b

Fig. 2. Photomicrographs of a similar experiment, to that described in Figure 1, except that the specimens were removed at 48 hours. In section a, note the coagulation of the dermis and the intact epithelium. In section b, note the disappearance of the epithelium and the intense reaction with edema and infiltration of leucocytes. × 34.

Indeed, immediately after immersion the involved skin was hard and coagulated, unlike the skin with less severe injury, which usually showed no particular gross change immediately. With the development of dry gangrene, a line of demarcation formed as with wet gangrene, but infection of the hard, dry skin did not occur, though it tended to slough quite easily, a phenomenon we have observed in similar lesions clinically. Dry necrosis tended to occur more readily over the dorsum of the thigh than the inner surface, which was more apt to show a moist necrosis. Microscopic section showed no alteration in the normal appearance of the epithelium, the nuclei being intact even though the tissue was examined 24 or more hours after the injury. However, the fibers of the dermis were swollen and stained deeply. No edema or inflammation was seen (Figs. 1a, 2a, and 3a). Indeed, the tissue may be said to have been fixed by the heat almost as if the skin had been immersed in a fixing fluid. However, a narrow zone between the normal and coagulated skin often exhibited the wet necrosis which has been described.

Which of the 3 types of lesions just described actually occurred depended upon the duration of the burn stimulus as well as upon its intensity, although other factors are apparently decisive. These other factors undoubtedly deal with the ability of the skin to cool itself, i.e., its ability to carry off the heat and thus avoid the effects of the thermal stimulus. This cooling influence is undoubtedly mediated largely through the blood flow, although loss of heat by conduction and radiation may also play a rôle. The cooling effect of the blood flow is indicated by the following observations.

Necrosis is more apt to occur in the skin over bony prominences where pressure is more likely to develop. This pressure, by interfering with blood flow, undoubtedly increases the likelihood of severe injury. It is probably for the same reason that contact (pressure) methods of producing thermal burns produce a much more severe burn with a lower temperature than similar burns produced without actual contact of the source of heat.

The skin of the extremities invariably shows a greater degree of damage than the torso. For example, the toes react more seriously to the same thermal stimulus than the thigh or lower abdomen. This is most likely due to the fact that the blood supply of the leg and foot is poorer because it is more terminal and has fewer collaterals.

When one observes the burn produced by pouring heated oil (180 degrees C.) over the surface of the torso, the center will become necrotic, whereas the periphery will merely show edema. This difference is often seen in clinical burns, the more severe lesion occurring in the center, the periphery showing much less extensive damage. It seems obvious that the uninvolved blood supply at the periphery carries off the heat and thus minimizes the injury.

ANALYSIS OF OBSERVATIONS

Although the experiments herein described deal primarily with the correlation of the nature of the local lesion with the thermal stimulus, they suggest interesting inferences between the severity of the local lesion and the systemic manifestations. Thus the production of inflammatory edema alone is clearly the cause of loss of plasma leading to hemoconcentration, fall of blood volume, and the physical changes responsible for surgical shock. These systemic changes are transient, however, and unless too severe, are combated by the compensatory mechanisms of the body or corrected by plasma transfusions. On the other hand, when the thermal stimulus produces a necrosis of the skin, the *type of necrosis*, not merely its *depth*, becomes of crucial significance. Familiar to most surgeons are differences between wet and dry gangrene of the extremity in so far as the presence or absence of systemic manifestations is dependent thereon. It would seem from the experiments herein reported that a similar difference may occur in the necrosis of skin produced by a burn. True enough, infection always enters the picture and after a sufficient time has elapsed undoubtedly accounts for many of the systemic manifestations. However, many systemic effects which become apparent before infection gains a foothold may be due to the presence of wet autolyzing tissue. The fact that hemorrhage in the adrenal was not observed during the production of inflammatory edema but only with the production of wet necrosis adds further evidence to the probability of this mechanism. While further study is indicated, there is increasing recognition that the presence of such damaged tissue is an important factor in shock and that such "toxic" factors may account for certain early deaths in extensive burns adequately treated with plasma transfusions.

From the practical point of view the experiments described herein assume clinical significance because they point out that the present classification of burns is inadequate in that it fails to differentiate between wet and dry necrosis. Such a differentiation may prove important by explaining certain severe clinical manifestations not due to loss of plasma.

a

b

Fig. 3. Photomicrographs of skin subjected to thermal injury. In section a, the skin was immersed at 100 degrees for 30 seconds. Specimen removed at 48 hours. Note the coagulation of the dermis and the intact epithelium and relative absence of inflammatory reaction. In section b, skin was immersed at 100 degrees for 10 seconds. Specimen removed at 48 hours, at the line of demarcation. Note on the left the disappearance of the epithelium and the intense inflammatory reaction. The intact epithelium of the uninjured skin is noted on the right. × 34

SUMMARY

Experimental thermal injuries are described and the production of 3 types of skin damage, i.e., edema, wet necrosis, dry necrosis, with variations in the intensity and duration of the burn stimulus as well as with the cooling effect of blood flow are correlated. The importance of differentiating wet and dry necrosis in human burns is discussed and evidence is presented suggesting that the former lesion may produce "toxic" manifestations.

REFERENCE

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2. HARKINS, H. N. The Treatment of Burns. Springfield, Ill., and Baltimore, Md.: C. C. Thomas, p. 30, 1941.

LATERAL RUPTURE OF THE CERVICAL INTERVERTEBRAL DISCS

A Common Cause of Shoulder and Arm Pain

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PAIN in the arm and shoulder is a complaint almost as common as pain in the back and leg. These symptoms are too frequently called neuritis—toxic or inflammatory in origin. This misconception has been corrected with respect to back and leg pain, due primarily to a better understanding of the mechanical factors involved in weight-bearing. However, the various pathological lesions which commonly cause arm pain are still generally misunderstood.

The primary purpose of this report is to call attention to the rôle of the lower cervical intervertebral discs in the production of shoulder and arm pain. Also, an effort will be made, on the basis of neurological symptoms and signs, to clarify the various painful radicular syndromes affecting the upper extremity.

The data upon which statements in this paper are based were collected from 12 verified cases of ruptured cervical discs and are summarized in Table I.

LITERATURE

Most published reports of cervical intervertebral disc ruptures have indicated that the lesion is most likely to be confused with neoplasms of the cervical cord. It has been generally believed that cervical herniations of the nucleus pulposus occur near the midline of the anterior wall of the neural canal and, therefore, cause symptoms by compressing the spinal cord. However, Semmes and Murphy in a recent article describe the relatively minor symptoms produced by lateral ruptures of the cervical intervertebral discs and suggest that these cases are far more common than those in which the spinal cord is compressed. Their lucid report promises to become a landmark in the understanding of the painful arm and shoulder.

Other observers have described the symptoms produced by bony spurs in the intervertebral foramina compressing the cervical nerve roots. Nachlas quite rightly indicated that most cases of scalenus anticus syndrome were really cases of cervical root compression at the intervertebral foramina, and he obtained relief in many of them by traction on the cervical spine. Oppenheimer and associates (12, 13), after the study of 50 similar cases, came to the same conclusion. Keyes and Compere called attention to these hypertrophic bony changes but indicated that the lesion was probably initiated by a damaged intervertebral disc at the site of the bony spur and that primary cervical arthritis rarely causes localized root compression.

The rôle of the scalenus anticus muscle in the production of arm and shoulder pain has been stressed by numerous authors. Unfortunately, its importance has been overemphasized in some quarters, and as a result many disappointing operations have been performed and much time has been wasted in misdirected conservative treatment.

ANATOMY AND PHYSIOLOGY

The cervical spinal canal is more nearly filled with nervous tissue than either the dorsal or lumbar regions; consequently, any intraspinal mass causes early symptoms of cervical cord deficit. The cervical roots, unlike the dorsal and lumbar roots, emerge from the dura mater at right angles and lie immediately over the intervertebral discs. As a consequence, a lateral protrusion of a cervical disc may compress the nerve root against the

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ligamentum flavum, lamina, pedicle, or facet without much damage to spinal cord (Fig. 1).

The intervertebral foramina of the cervical spine have long vertical diameters with shallow anteroposterior diameters. The roots, as they pass through these foramina, are especially vulnerable to pressure from a small bony spur or a laterally placed herniation of the nucleus pulposus (Fig. 2).

The points of greatest strain in the cervical spine are at the 5th and 6th interspaces. Roentgenologists have long recognized the frequency with which the intervertebral disc is narrowed at these levels. The narrowed disc may be associated with x-ray evidence of localized arthritis (Fig. 3). Many patients with such x-ray findings have no symptoms referable to the neck or arms.

The cervical spinal cord is composed of 8 segments with 8 anterior roots and 7 posterior roots; the 1st cervical posterior root is usually absent. The 1st cervical motor root leaves the canal between the occiput and the atlas. The 8th cervical nerve exits at the foramen between the 7th cervical and 1st thoracic vertebrae. Therefore, a disc lesion at C-5 (between the 5th and 6th cervical vertebrae) causes direct impingement upon the 6th cervical nerve root, and one at C-6 (between the 6th and 7th cervical vertebrae) compresses the 7th cervical root. Recognition of this anatomical arrangement is important if the lesions are to be localized accurately on clinical findings.

PATHOLOGY

Cervical ruptured discs may follow severe or minor injuries to the neck; many patients, however, give no history of trauma. In analyzing the reported cases, it would appear that those cervical disc lesions which compress the spinal cord are much more frequently the result of trauma than the small laterally placed lesions which cause only arm and shoulder pain. That degenerative processes play an important rôle in the production of the lesion is indicated by the frequency with which there is roentgen evidence of localized arthritic spurs and narrowing of the intervertebral disc at the site of the lesion.

The quantity of nucleus pulposus in a cervical disc is relatively small as compared with the lumbar region. As a consequence, even in acute cases, one is surprised to find at operation a relatively small mass compressing the nerve root or even the spinal cord. In many instances, the herniated portion of the disc is surrounded by bone. These bony prominences, known as osteophytes, may project into the intervertebral foramina.

SYMPTOMS

Pain and *stiffness* of the *neck* are usually the first symptoms. Not infrequently, after the initial bout of stiff neck, the patient will experience no further local discomfort. Symptoms may consist entirely of pain into the shoulder and down the arm into the hand. Any sudden movement of the head or neck, coughing, straining, or sneezing may intensify the pain or produce a feeling of "electrical shock" into the arm and hand.

The pain is usually made worse by maintaining a single position. Not infrequently, a patient, in order to relieve the discomfort, will get out of bed several times at night to change his position completely. The points of maximum pain are the base of the neck, the tip of the shoulder and the arm down to the elbow. Occasionally, the pain extends into the hand, but paresthesias and numbness in the hand are usually more aggravating than is the pain.

Not infrequently, the patient states that his whole hand "goes to sleep," that it has a feeling of numbness, that it feels cold to touch, and that it appears blue in color. As will be pointed out later, these vascular symptoms are part of an associated scalenus anticus muscle spasm which may completely becloud the clinical picture. Weakness of the arm and at times atrophy and fibrillation of muscles are frequently noted and may be severe.

If the lesion is a large one and compresses the cervical cord, the usual symptoms of spinal cord deficit are present. These symptoms are identical with cervical cord tumor and will not be reiterated here.

SIGNS

Sensory. Strangely, many patients complain severely of recurrent numbness and tingling into the hand and forearm, and yet no sensory deficit can be demonstrated by the

TABLE I.—IMPORTANT CLINICAL AND ROENTGENOGRAPHIC DATA FROM 12 VERIFIED CASES OF RUPTURED CERVICAL DISCS

Case number Initials	Age Sex	Location of lesion	Side of lesion	Duration of symptoms	Neck pain	Shoulder pain	Arm pain	Pain into hand and fingers	Intensified by coughing and sneezing	Numbness	Paresthesias	Vascular symptoms	Objective sensory loss	Motor weakness	Tendon reflexes	Localized spinal tenderness	Radiating percussion pain	Neck compression test	Associated scalenus anticus syndrome	Narrowed disc	Osteophytes	Myelogram	Date of operation—1943
1. H.T.	40 M	C-5	Rt.	2 mos.	Yes	?	Yes	Yes	Yes	Yes	Yes	Marked	C-6	?	Biceps, absent	Yes	Yes	4+	Mild	Yes	Yes	Not done	1-4
2. G.C.	41 M	C-5	Rt.	3 mos.	Yes	Yes	Yes	No	No	Yes	Yes	Marked	C-6	No	Biceps, diminished	Yes	Yes	4+	Marked	Yes	No	Defect C-5	2-5
3. B.D.	36 M	C-5	Rt.	2 mos.	Yes	Yes	Yes	Yes	No	Yes	Yes	None	C-6	Yes	Biceps, absent	Yes	Yes	4+	No	Yes	Yes	Defect C-5	2-24
4. T.P.	32 M	C-6	Rt.	3 mos.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	None	?	?	No change	Yes	No	4+	No	No	No	Defect C-6	5-25
5. W.R.R.	50 M	C-5 and C-6	Lt.	4 yrs.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	None	C-6 and C-7	Yes Triceps and Biceps	Biceps and triceps, absent	Yes	Yes	4+	No	Yes	Yes	Defect C-5 and C-6	5-28
6. C.J.H.	34 M	C-6	Rt.	2 mos.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	None	C-7	Slight	Triceps, absent	Yes	Yes	4+	Mild	No	No	Defect C-6	6-2
7. J.A.L.	44 M	C-6	Lt.	10 yrs. recurrent	Yes	Yes	Yes	Yes	Yes	Yes	Yes	None	C-7	No	No change	Yes	Yes	4+	No	Yes	Yes	Defect C-6	7-13
8. D.T.S.	28 M	C-6	Lt.	5 mos.	Yes	Yes	Yes	Yes	No	Yes	Yes	Slight	C-7	No	Triceps, reduced	No	No	4+	Slight	Yes	No	Defect C-6	7-15
9. T.H.M	41 M	C-6	Rt.	5 mos.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Slight	None	Yes Triceps	Triceps, absent	Yes	Yes	4+	Mild	No	No	Defect C-6	9-2
10. H.R.K.	35 M	C-6	Lt.	5 mos.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	None	C-7	Yes triceps	No change	No	No	4+	No	Yes	Yes	Defect C-6	10-18
11. J.M.B.	44 M	C-6	Rt.	2 mos.	Yes	Yes	Yes	Yes	No	Yes	Yes	None	C-7	Yes diffuse	No change	No	No	2+	Marked	Yes	Yes	Normal	11-10
12. T.P.M.	47 M	C-6	Lt.	6 mos.	Yes	Yes	Yes	Yes	Yes	No	Yes	None	None	Yes	Triceps, absent	Yes	Yes	4+	No	Yes	Yes	Defect C-6	11-22

No history of trauma except in case 1, broken neck in 1935; and case 5, fracture C-5 in 1935.

usual clinical tests. In the same case, if the neck and head are tilted toward the painful side and pressure is applied to the top of the head, the whole radicular pattern may be reproduced. If the compression has become long and severe, sensory deficit can usually be demonstrated with ordinary tests. Paresthesias can occasionally be demonstrated by gently stroking the skin in the involved dermatome. The sensory patterns associated with lesions of the sixth and seventh cervical roots are illustrated in Figures 4 and 5.

Motor. Objective muscular weakness may be difficult to demonstrate even though the patient complains that the involved extremity is weaker than normal. When muscle deficit can be demonstrated, it may have great diagnostic as well as localizing significance. The biceps brachialis is supplied chiefly through the 5th and 6th cervical nerve roots; whereas, the triceps brachialis is supplied chiefly through the 7th and 8th cervical nerve roots. Therefore, weakness of the biceps with normal triceps function frequently occurs with lesions of the 6th cervical root (the disc between the 5th and 6th cervical vertebrae). A weak triceps and a normal biceps indicate a lesion of the 7th cervical nerve root (the disc between the 6th and 7th cervical vertebrae).

Reflex changes. Lesions at C-5 disc are characteristically associated with diminution

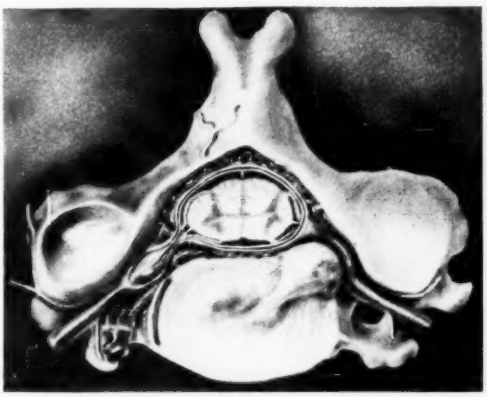

Fig. 1. Diagrammatic sketch illustrating the mechanism by which a laterally placed ruptured disc may compress the nerve root without appreciable impingement upon the spinal cord.

or absence of the biceps reflex; whereas, lesions at C-6 disc are associated with diminution or absence of the triceps jerk. The other tendon reflexes in the upper extremity are usually not involved with lesions at these levels.

Spinal tenderness at the site of the lesion is a frequent finding as in lumbar herniations of the nucleus pulposus. Percussion or pressure to the painful side of the midline may reproduce the radicular pain or paresthesias—radiating percussion pain (Fig. 6).

Fig. 2, left. Case 1. Oblique view of cervical spine showing narrowing of intervertebral foramen at C-5. Note small osteophytes on anterior margin of the foramen.

Fig. 3. Case 1. Lateral view of cervical spine. Arrow points to narrowed disc between 5th and 6th cervical vertebrae. Note chip fracture of superior surface of body of 5th cervical.

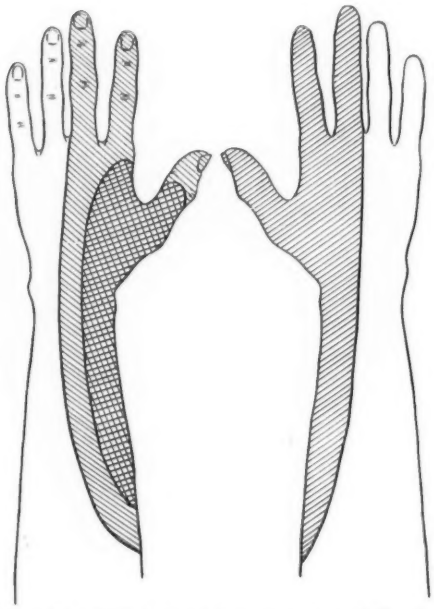

Fig. 4, left. Dorsal view of forearm and hand illustrating the approximate areas into which pain or paresthesias radiate or in which sensation is diminished when the 6th and 7th cervical roots are compressed. The cross hatched area corresponds roughly to the 6th cervical dermatome; the lined area to the 7th cervical dermatome.

Fig. 5. Ventral view of the forearm and hand illustrating the approximate area into which pain or paresthesias radiate or in which sensation is diminished when the 7th cervical root is compressed.

The most important diagnostic test and one that is almost pathognomonic of a cervical intraspinal lesion is the "*neck compression test*" (Fig. 7). Tilting the head and neck toward the painful side may be sufficient to reproduce the characteristic pain and radicular features of the lesion. Pressure on the top of the head in this position may greatly intensify the symptoms. Tilting the head away from the lesion usually gives relief.

DIFFERENTIAL DIAGNOSIS

Bony lesions of the cervical spine, either neoplastic or inflammatory, may compress one or more nerve roots in the foramina and cause radicular pain similar in every respect to cervical disc lesions. Neoplasms of the spinal cord, particularly those arising from the nerve roots, may give identical symptoms.

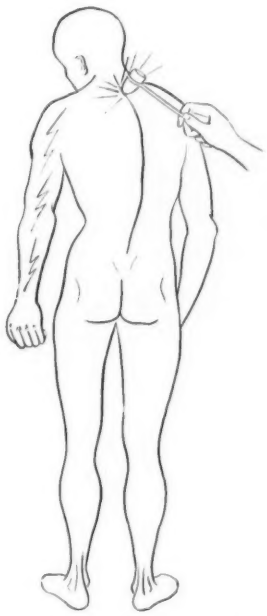

Fig 6. *Radiating pain* can frequently be produced by percussing directly over the lesion. When positive this test causes pain or paresthesias to radiate into the shoulder and arm.

Scalenus anticus compression, with or without cervical rib, is the lesion most easily confused with ruptured cervical discs. The most important differential feature is that the nerve pain and paresthesias from scalenus anticus compression are referred to the dermatomes of the *1st thoracic* and *8th cervical* nerve roots (the ulnar distribution); whereas, the pain and paresthesias of cervical disc lesions are in the distribution of the 6th or 7th cervical nerves (radial or median distribution). Cervical ruptured discs below the level of the 6th interspace rarely occur; therefore, it should not be too difficult to separate the two lesions in the differential diagnosis. Furthermore, the scalenus anticus syndrome characteristically has a vascular component since the subclavian artery is so easily compressed against the 1st rib in the scalenus angle.

It should not be forgotten that any lesion of the cervical spine may produce spasm of the scalenus muscle. It is not uncommon, in fact, to have the clinical features of a ruptured

Fig. 7. Method of performing neck compression test in patients with suspected ruptured cervical discs.

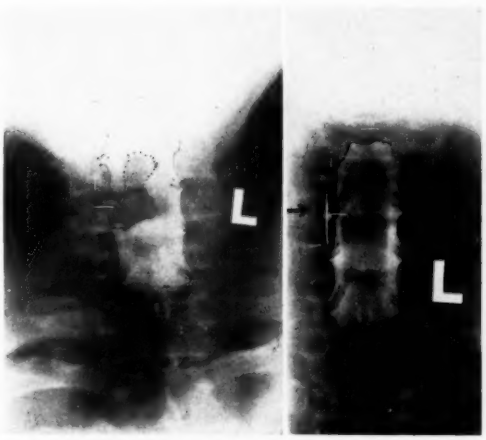

Fig. 8, left. Case 2. Pantopaque myelogram. Arrow points to a large filling defect in the opaque column. Ordinarily, a laterally placed ruptured disc does not produce such a large deformity.

Fig. 9. Case 3. Pantopaque myelogram. Arrow points to the obliterated axillary pouch at C-5. This deformity is characteristic of a laterally placed ruptured disc pushing into the intervertebral foramen.

cervical disc overshadowed by a superimposed scalenus syndrome (cases 2 and 11 Table I). However, if by compressing the neck toward the painful side, pain, paresthesias, and numbness into either the 6th or 7th cervical dermatome are produced, one may be sure that the symptoms are not due to scalenus compression, for these nerves cannot be involved by pressure within the scalenus angle.

ROENTGEN EXAMINATION

Plain x-ray films of the cervical spine give invaluable evidence in many cases of ruptured cervical discs. The lateral films usually show narrowing of the interspace with loss of the normal lordotic curve even in a hyperextended position. Oblique views may show narrowing of the intervertebral foramen with proliferation of bone in the foramen (osteophytes). These proliferative bony changes

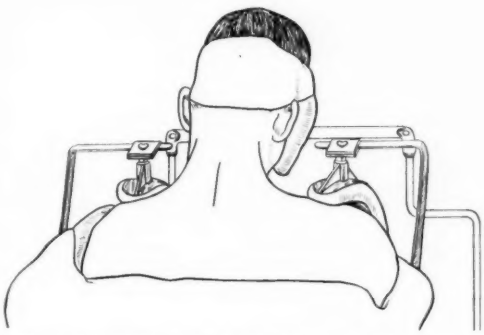

Fig. 10. Posterior view of patient in the upright position for lower cervical hemilaminectomy. Note line of operative incision.

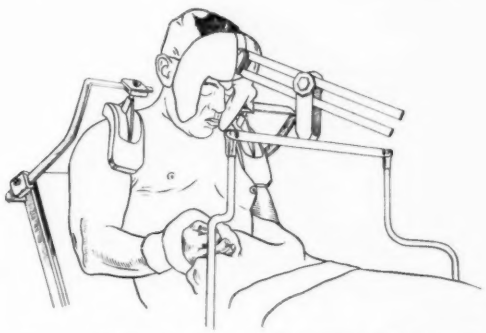

Fig. 11. Oblique view of patient in the upright position, using the head rest devised by Captain W. McK. Craig, M.C., U.S.N.R., Naval Medical Center, Bethesda, Md.

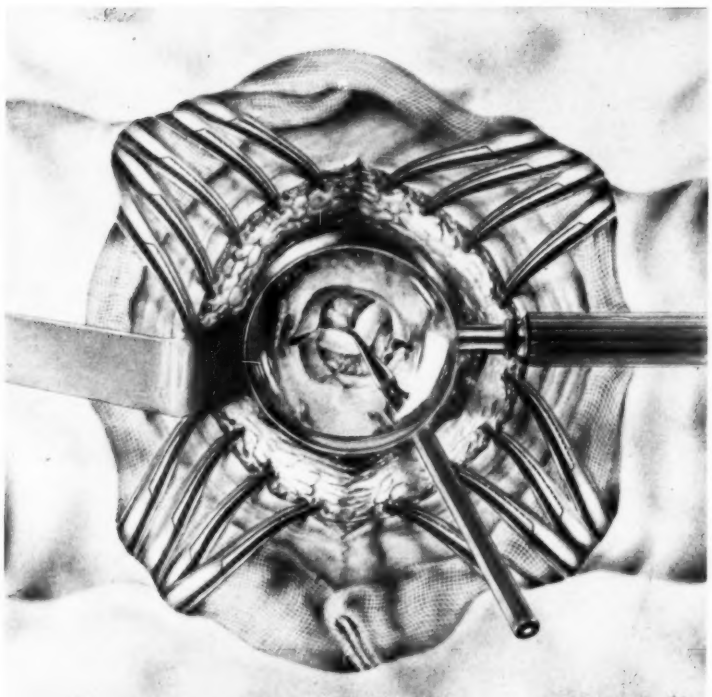

Fig. 12. Drawing of operative field illustrating the exposure of the 6th cervical root with minimal removal of bone. Note herniated nucleus pulposus presenting beneath the retracted nerve root.

may be bilateral even though the symptoms are unilateral.

Pantopaque myelography is an exceedingly accurate method of diagnosing ruptured cervical discs. In the prone position, 6 cubic centimeters of pantopaque are injected into the subarachnoid space by lumbar puncture. Before tilting the table, the patient's head is held in a fully extended position by placing a small pillow under the chin in order that the contrast material does not run into the basal cisternae of the skull. The head of the table is then tilted downward just enough to permit the pantopaque to collect in the cervical gutter. A series of anteroposterior films are then made after balancing the column at the desired level with the fluoroscope. The anterior surface of the cervical canal is outlined clearly, and each nerve root with its axillary pouch may be accurately identified. Larger lesions show a defect in the column (Fig. 8). Smaller lesions may show no defect other than an obliteration of an axillary pouch and root sleeve (Fig. 9).

TREATMENT

Conservative. Conservative measures, undoubtedly, have an important place in the treatment of ruptured cervical intervertebral discs, particularly if the symptoms are purely radicular with no evidence of cord compression. If the lesion is suspected of being a fairly large one (as indicated by muscular wasting or marked sensory loss in the arm with or without signs of spinal cord deficit),

then prompt operative intervention is advisable because of the dangers of irreparable damage to the cervical cord.

For the milder cases, a period of bed rest with halter traction may give lasting relief. The patient should have absolute bed rest and from 5 to 10 pounds of traction applied continuously. If after 3 or 4 days there is no relief of radicular pain and muscle spasm, further conservative treatment will probably be of little avail. If the patient is comfortable in traction and the pain recurs mildly when weight-bearing is resumed, a well fitting cervical collar support may give symptomatic relief.

Manipulation of the cervical spine in the presence of a ruptured intervertebral disc is a dangerous procedure and may result in irreparable damage to the spinal cord.

Operative technique. The upright position is ideal for operations in the lower cervical region (Figs. 10 and 11). Procain nerve block or endotracheal ether anesthesia is equally satisfactory.

A straight incision is made from the spinous process of the vertebra above to the one below the level of the lesion. The muscles are freed from the spinous processes on the side of pain, and, after denuding the laminae of soft tissue, a triangular piece of bone is removed from the laminae above and below the lesion with a small dental chisel. This exposes the ligamentum flavum which in the lower cervical region is almost completely covered with bone. The inner edge of the articular facet is then chiseled away, thus providing good exposure of the root and the lateral edge of the dura mater covering the cord (Fig. 12). If the bony incision is placed correctly even the predural fat need not be disturbed. The spinal root will be found to be wedged tightly into the intervertebral foramen by the anterior mass. With careful dissection, the root is separated from the mass and retracted either upward or downward in order that the mass may be removed with as little trauma to the root as possible. In case of the "soft" disc, bits of typical herniated nucleus pulposus may be lifted out of the tear in the annulus fibrosus. If the lesion is an old one and has become surrounded by a bony spur, it may be necessary to chisel away the spur and remove the base of it with a curette. Then the posterior rim of the intervertebral foramen is removed completely with a nasal punch in order that complete decompression of the involved nerve root is provided.

After all bleeding is carefully controlled the usual anatomical closure of the wound is carried out by means of interrupted sutures of black silk.

Postoperative treatment. The patient is kept in the recumbent position just so long as there is residual pain in the arm and shoulders. Some patients are comfortable immediately, while others have rather severe radicular pains for several days. A number of our cases have been out of bed on the first postoperative day; others have not been able to bear weight without pain for 10 to 12 days. With the operation performed in this manner, there is very little damage to the weight-bearing structures of the neck and, therefore, early ambulation is not considered harmful.

RESULTS

Of the 12 patients operated upon, all have been relieved of their radicular pain within 2 weeks following operation — most of them earlier. In each instance (with the exception of the last one who was operated upon but 3 weeks ago) the patients have been able to return to military duty without disability.

OBSERVATIONS

The true or relative incidence of ruptured cervical discs cannot now be stated because of insufficient data. Our experiences with both cervical and lumbar ruptured discs at the Walter Reed General Hospital indicate that the relative frequency of the two lesions is 1:12, i.e., there were 12 cervical and 143 lumbar ruptured discs verified by operation during the first 11 months of 1943. During this same period of time, there were many more clinical diagnoses made of lesions in both locations, but since they were not verified by operation no attempt was made to use them statistically. When the clinical features of ruptured discs in the cervical region are as well understood as are those in the lumbar regions this ratio will probably be reduced.

The statistical analysis of data in Table I discloses some pertinent details requiring further emphasis.

1. There was but 1 patient under 30 years of age (28 years), and there were 7 patients aged 40 years or older. This would indicate that the cervical disc lesions occur more frequently in the upper age group. This is in contrast to the ruptured lumbar discs as seen in the personnel of the military service where age or physical fitness appears to be of minor significance.

2. There were but 2 patients (16%) who gave histories of trauma precipitating the onset of symptoms. This, again, is in contrast to the lumbar disc lesions in which a history of trauma is obtained in approximately 60 per cent of cases.

3. Pain and paresthesias radiating from the neck into the shoulder, arm and hand were constant findings. Moreover, these symptoms were consistently exaggerated by the neck compression test—a sign that we consider to be almost pathognomonic of a laterally placed ruptured cervical disc.

4. Twice as many ruptured cervical discs occur at the 6th interspace as at the 5th interspace. In our series, there were 8 at C-6, 3 at C-5 and in 1 instance, there was a lesion at both C-5 and C-6. The diagnosis of the double disc (Case 5) was made on clinical findings, verified by pantopaque myelogram, and proved at operation.

SUMMARY

1. Lateral rupture of the lower cervical intervertebral discs is a common cause of radicular pain affecting the upper extremity.

2. The clinical syndrome is remarkably constant and easily recognized.

3. Accurate localization of the lesion on clinical findings is usually possible. The salient features are:

The 5th cervical disc. (a) Pain radiating from the neck into the shoulder and arm with paresthesias (needles and pins or numbness) into the posterior aspect of the thumb. Symptoms always aggravated by tilting the head to the painful side. (b) Weakness or absence of the tendon reflex of the biceps brachialis muscle.

The 6th cervical disc. (a) Pain radiating from the neck into the shoulder and arm with paresthesias (needles and pins or numbness) into the index, middle, and perhaps the ring fingers and tip of thumb. Symptoms aggravated by tilting head to the painful side. (b) Weakness or absence of the tendon reflex of the triceps brachialis muscle.

4. The lesion can in most instances be accurately verified by pantopaque myelography.

5. Conservative treatment relieves symptoms in many cases. When conservative measures fail, operative removal of the lesion is justified on the basis that it is a simple, safe procedure, and the results are excellent.

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AN EXPERIMENTAL STUDY OF SULFONAMIDE IMPREGNATED SUTURES

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RECENTLY there has been much experimental and clinical work carried out concerning the local uses and action of the sulfonamides. Because of the beneficial effects consistently reported with the local employment of sulfonamides in contaminated wounds, and since suture material so many times is a factor in wound infection, we decided to determine whether or not absorbable and nonabsorbable sutures impregnated with sulfonamides would reduce the incidence or severity of surgical wound infections.

Ochsner and Meade, after studying various suture materials embedded in surgical wounds, concluded that cotton was the most satisfactory of all, since it produced a minimal tissue reaction in contrast to the "wet" or "proliferative" reaction caused by catgut. They also observed that infection occurred more often when catgut sutures were employed. However, those who have worked with nonabsorbable sutures are not unaware of their outstanding disadvantage, namely, that when infection occurs in a surgical wound closed with such sutures the regenerative process is prolonged, and healing will not take place until all the infected sutures are either removed or extruded through a sinus tract. Keeping this fact in mind, the writers undertook experiments using sulfonamide impregnated sutures, hoping to determine whether or not the incidence and degree of infection would be lessened when contaminated wounds were closed with such sutures or had them buried in the wound.

In noncontaminated surgical cases as in laparotomies and hernioplasties, it is not uncommon for wound infections to form despite the strictest aseptic precautions, and most often these infections are found to take place in the subcutaneous layer of the abdominal wall. Because of this observation, we planned to reproduce experimentally a similar infection in the abdominal wall of the dog. Also, since Staphylococcus aureus is known to be the most frequent causative organism found in surgical wound infections, we selected for our experiments a strain of hemolytic Staphylococcus aureus[1] isolated from contaminated human blood in a blood bank. The suture material employed in this study consisted of No. 20 cotton, containing 10.5 per cent sulfadiazine by weight; No. 20 cotton containing 44.2 per cent sodium sulfathiazole sesquihydrate; No. 0 catgut containing 4.6 per cent sulfanilamide; and No. 0 catgut containing 2.3 per cent sulfathiazole. In the control wounds, we employed sutures that were identical in every respect, except that they were not impregnated with sulfonamides. There were no obvious differences noted in the tensile strength between the impregnated sutures and our controls.

To proceed properly with our experiment, in which a comparative study of the merit between impregnated and unimpregnated sutures was to be made, it was imperative that we first determine existing questions: the minimal concentration of Staphylococcus aureus required to produce consistently an infection in our surgical wounds and the traumatic effect of the ligatures used on the degree of infection and wound healing.

To maintain consistency in our observations, we believed that the evaluation of the

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[1]The Staphylococcus aureus was gram positive; it produced acid in inulin, sucrose, lactose, maltose, dextrose, and mannitol broth, and was dulcite negative and hemolized blood. The virulence of the bacterial strain was checked on several occasions, by injecting 0.2 c.c. of a 1:10 dilution of a 24 hour broth culture into uninjured subcutaneous tissue of the abdominal wall of rabbits. These rabbits developed localized reddened, swollen areas up to one-half inch in diameter at the site of injection, while control injections of sterile saline solution produced no sign of local inflammation when examined after 48 and 120 hours. The cultures employed in these experiments were 22 to 24 hour broth cultures incubated at 37 degrees C.

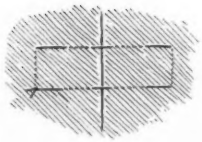

Fig. 1. The dotted line represents the suture as it lies underneath the surface in the epidermal layer. The solid line illustrates the suture as it is seen lying on the surface of the wound. The vertical line represents the incision which has been made.

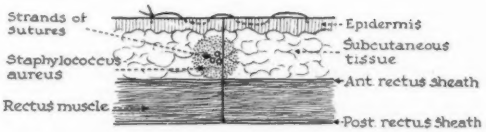

Fig. 2. A diagrammatic sketch of the course of the intracutaneous suture, demonstrating how in passing only through the epidermal layer it avoids becoming contaminated by the implanted organisms lying in the subcutaneous tissue.

incidence and the degree of wound infection should be based upon a standard set of criteria that would be applicable to all wounds. Our gross observations therefore included notations as to the presence or absence of redness, swelling, wound separation, and the accumulation of serous or purulent material. The degree of bacterial growth was determined by making bacterial cultures of these wounds and then counting the number of colonies grown after a 24 hour incubation period. Then, by employing the same criteria used by other workers, we decided further to evaluate wound infection and wound healing by taking biopsy specimens from each wound on the 6th postoperative day in order to observe any differences that might exist microscopically. Here the presence or absence of edema, polymorphonuclear leucocytosis, giant cells, fibroplasia, fibrosis, and capillary proliferation were particularly sought.

The technique employed in our experimental study to determine the dosage of bacteria required to produce wound infections consistently in contaminated traumatized and untraumatized surgical wounds was as follows:

1. Each dog was anesthetized and the abdominal wall was shaved. The skin was painted with tincture of iodine, and sterile drapes were applied.

2. A skin incision 2.5 inches long was made in each of the four quadrants of the abdomen and carried down as far as the anterior rectus sheath.

3. In each wound, hemostasis was obtained by the use of 6 No. 20 plain cotton ligatures. In instances in which less than 6 ties were required for hemostasis, knots were purposely tied in the nonbleeding tissue to make up the same number. In the upper and lower wounds on the right side of the abdomen of each dog, hemostasis was accomplished by the use of mosquito forceps, so that as little tissue as possible was crushed in the clamping. We considered these wounds to be "nontraumatized." However, in the upper and lower wounds on the left side of the abdomen, hemostasis was accomplished by the use of large Ochsner hemostats, so that an excess of tissue was included in the crushing. These left-sided wounds we classified as "traumatized." Each of the 4 wounds were then closed by inserting 6 intracutaneous interrupted cotton sutures in such a manner as to avoid passing through the contaminated subcutaneous tissue. This special suture, devised by Lieutenant Glassman (Figs. 1 and 2) had the advantage of confining our infections to the subcutaneous layer alone, thereby preventing the infection from traveling along the course of the suture to the surface of the wound, or bacteria on the skin from secondarily invading the subcutaneous tissue, or confusion of the microscopic picture due to reaction to the suture used in skin closure with the reaction to the suture employed for hemostasis.

4. Each wound was contaminated by introducing 0.2 cubic centimeter of a bacterial suspension of Staphylococcus aureus into the subcutaneous layer by means of a long sterile pipette. Collodion dressings and canvas binders were employed to prevent the animals from contaminating and removing the sutures with their teeth.

5. As stated previously, gross inspections and bacteriological cultures were made of each wound after 48 and after 120 hours. A relatively quantitative method was used to determine the number of bacteria in the wounds. The technique involved the withdrawal of a given standard amount of serous material by means of a sterile glass capillary tube intro-

duced into the depth of the wound at the time of sampling. By the use of tubes of a uniform diameter the volume of sampling was kept constant throughout the experiments. Material allowed to enter the tubes at the time of sampling was kept constant throughout the course of the experiments. The amount of material withdrawn was inoculated into molten agar and poured into Petri plates. Colonies were counted after 48 hours of incubation at 37 degrees C.

6. Biopsy specimens were taken from each wound on the 6th postoperative day.

At times, individual variations in response to trauma and bacterial infection did occur but not with such frequency as to interfere with the interpretation of our preliminary experiments (determining the bacterial dose), which were as follows:

1. The lowest bacterial dilution capable of producing a wound infection consistently was found to be 0.2 cubic centimeter of a 1:1000 dilution of a 22 to 24 hour culture of Staphylococcus aureus.

2. The traumatized wounds showed much poorer healing than those that were not traumatized as was evidenced by gross, bacteriologic, and microscopic examinations.

3. By microscopic comparison of the wound biopsy specimens, the traumatized ones were readily recognized by the presence of a greater collection of serum and polymorphonuclear leucocytes as well as a higher degree of necrosis.

Having succeeded in establishing a standard dose of bacteria which would result in artificially induced infection with a minimal amount of contaminant and trauma, we proceeded with our study to determine whether or not sutures impregnated with sulfonamide compounds would reduce materially the degree of bacterial growth, or favorably influence the course of healing of a contaminated wound. Four groups of experiments[1] were arranged: In the 1st group we used No. 20 cotton sutures impregnated with sulfadiazine; in the 2d group No. 20 cotton sutures impregnated with sodium sulfathiazole sesquihydrate; in the 3d group No. 0 catgut impregnated with sulfanilamide; and finally in the 4th group No. 0 catgut impregnated with sulfathiazole. With each group, controls were run in which identical unimpregnated sutures were used.

[1]The suture material used in these experiments was kindly prepared according to our specifications by Curity Suture Laboratories of Bauer & Black, Division of Kendall Company.

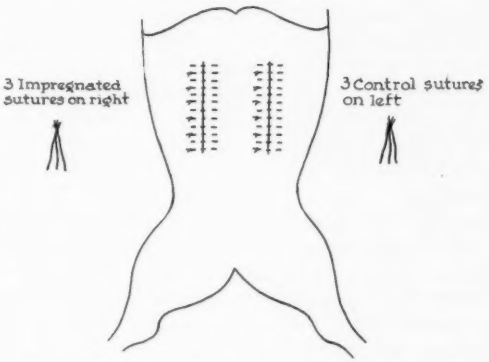

Fig. 3. A skin incision 5 inches long is made on either side of the midline. Three 5 inch strands of the impregnated suture to be tested, knotted together at one end, are laid in the right wound while 3 strands of the suture controls are placed into the left wound. Six intracuticular mattress stitches are used to approximate the edges of each wound as shown in Figures 1 and 2.

Since a moderate increase in the amount of trauma associated with closure of the wound reflected so sharply in the rate and type of healing (a fact which after all is quite well known), we decided to embed strands of suture material rather than knots, since it would be difficult or impossible to include the same amount of tissue with the ligature in each of the experiments. In other words it appeared that we could standardize the experiments better by excluding trauma as much as possible.

The technique employed in our experimental study of artificially contaminated wounds in which sulfonamide impregnated sutures were embedded, was carried out as follows:

1. Each dog was anesthetized and the abdominal wall was shaved. The skin was painted with tincture of iodine and sterile drapes were applied.

2. A skin incision 5 inches long was made on either side of the midline and carried down to the anterior rectus sheath, as illustrated in Fig. 3. Hemostasis was obtained by grasping as little tissue as possible in our clamps and employing the same number of ligatures in each wound.

3. Three 5 inch strands of the impregnated suture to be tested, knotted together at one end, were laid in the right wound while 3 strands of control suture (not impregnated) were placed in the left wound. Six intracuticular mattress stitches as seen in Figures 1 and 2 were used to approximate the edges of each wound.

4. The wounds were then contaminated by introducing by means of a long pipette 0.2 cubic centimeter of broth cultures of Staphylococcus aureus either undiluted or diluted 1:10 and 1:100 with physiological saline. Collodion dressings and canvas binders served in preventing injury and contamination from extraneous sources. The examination of these wounds, as in the aforementioned experiments, were carried out after 48 and after 120 hours.

In part A of group 1 experiment No. 20 cotton sutures impregnated with sulfadiazine were embedded in surgical wounds contaminated with a 0.2 cubic centimeter of undiluted culture of Staphylococcus aureus. The following observations were made:

1. Examination of wounds containing untreated and impregnated sutures, after 48 hours showed no gross differences except for the presence of more serum in the wounds containing the untreated sutures. But bacteriologic examinations revealed a reduction in the number of bacteria present in the wounds that contained the impregnated sutures.

2. Examinations after 120 hours revealed that the wounds containing the impregnated sutures appeared more normal than the wounds containing the untreated controls, as was evidenced by the smaller amount of serum, reduced bacterial count, and a lesser number of microscopic signs of infection.

In part B of group 1 experiment No. 20 cotton sutures impregnated with sulfadiazine were embedded in surgical wounds contaminated with 0.2 cubic centimeter of a 1:10 dilution of a culture of Staphylococcus aureus. The following observations were made:

1. Although there were no gross differences observed between the wounds containing plain cotton and those containing sutures impregnated with sulfadiazine, the bacterial cultures of the wounds containing impregnated sutures showed very noticeable reductions in their bacterial counts. In fact, we were able consistently to demonstrate a reduction in the bacterial count of approximately 50 per cent. Though no gross differences were noticed even after 120 hours, our cultures still showed a reduction of 60 per cent or more in the number of bacteria present in the wounds containing sutures impregnated with sulfadiazine.

2. The microscope examination of wounds containing impregnated sutures, further revealed that improved healing had taken place. This fact was evidenced by the smaller amount of serum present, fewer polymorphonuclear leucocytes, minimal necrosis, and a demonstrable increase in fibroplasia when compared with wounds containing untreated control sutures.

3. Examination of wound biopsy specimens after 14 to 21 days revealed that wounds containing impregnated sutures still possessed more advanced healing. The concentration of sulfonamide present in our suture material was in no case sufficient to produce any noticeable foreign body reaction.

In part C of group 1 experiment No. 20 cotton sutures impregnated with sulfadiazine were embedded in surgical wounds contaminated with 0.2 cubic centimeter of a 1:1000 dilution of a culture of Staphylococcus aureus. The following observations were made:

1. After 48 hours there were no gross differences noticed between those wounds containing untreated cotton sutures and those containing sulfadiazine impregnated cotton sutures. However, bacterial cultures taken from wounds containing the untreated sutures revealed the presence of slight bacterial infection, while cultures taken from the wounds containing the impregnated sutures were sterile.

2. After 120 hours, bacterial cultures revealed that the wounds containing untreated cotton sutures were still infected, while the wounds containing sutures impregnated with sulfadiazine remained sterile. Here again, the microscopic examinations of the wounds containing impregnated suture material showed a slight, but definitely better, healing.

From these findings we concluded that the presence of sulfadiazine in cotton suture material appears to be capable of preventing or

minimizing infection following inoculation of the wound with staphylococci as described. Although no gross improvement of wound healing was apparent, microscopic examinations of the wounds containing unimpregnated control sutures revealed definite evidence of retarded healing.

In group II experiment No. 20 cotton sutures impregnated with sodium sulfathiazole sesquihydrate were embedded in surgical wounds contaminated with 0.2 cubic centimeter of a 1:10 dilution of a culture of Staphylococcus aureus. The following observations were made:

1. The gross and microscopic findings were practically the same as those obtained with sutures impregnated with sulfadiazine, as described in part B of group I. In addition, the sutures impregnated with sodium sulfathiazole sesquihydrate showed a reduction in the bacterial count of over 75 per cent in most instances.

In group III experiment No. 0 catgut sutures impregnated with sulfanilamide were embedded in surgical wounds contaminated with 0.2 cubic centimeter of a 1:10 dilution of a culture of Staphylococcus aureus. The following observations were made:

1. After 48 hours no gross differences were seen between the wounds containing untreated catgut sutures, and those in which impregnated sutures were embedded. Cultures taken at this time from the wounds containing the impregnated catgut showed a reduction in the bacterial count of about 50 per cent over cultures taken from wounds containing untreated catgut controls. Surprisingly enough, after an interval of 120 hours, cultures obtained from the wounds containing the impregnated sutures gave a higher bacterial count while the microscopic findings revealed evidence of poorer healing. These observations led the writers to conclude that sulfanilamide impregnated catgut sutures afford only a transitory protection, if any, against bacterial infection.

In group IV experiment No. 0 catgut sutures impregnated with sulfathiazole were embedded in surgical wounds contaminated with 0.2 cubic centimeter of a 1:10 dilution of a culture of Staphylococcus aureus. The following observations were made: The sulfathiazole impregnated catgut sutures in surgical wounds proved just as disappointing as those that contained sulfanilamide. Here, again, we noticed that whatever bacteriostatic action they possessed was only transitory. In addition the microscopic picture showed a definite impairment of healing processes.

SUMMARY

The authors believe that these preliminary experiments with sulfonamide impregnated suture materials in infected wounds indicate that cotton sutures impregnated with sulfonamide compounds will reduce the growth of bacteria in minimally infected wounds and thereby favorably influence wound healing. On the contrary, catgut impregnated with sulfonamide exerts little or no beneficial influence on bacterial infection or wound healing. It is possible that the smaller amount of sulfonamide present in the catgut sutures may partially explain this observation though the nature of the suture material itself may be partially responsible. The importance of trauma upon bacterial infection and wound healing is reaffirmed.

SOLITARY CIRCUMSCRIBED TUMORS OF THE LUNG

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THE more common bronchogenic neoplasms arise in the major bronchi, and if untreated usually progress to obliterate the bronchus causing atelectasis of the distal lung (Fig. 1). This gives rise to a definite train of symptoms which usually consist of a dry, hacking cough, followed soon by hemoptysis, shortness of breath, wheezing, chest pain, and fever. As metastases occur the usual symptoms of anorexia, weakness, and weight loss typical of all extensive malignancies appear. Occasionally distant metastases, especially to bones, brain, or abdomen cloud the picture by causing more troublesome symptoms than those produced by a small primary lesion in the lung. There is, however, a group of primary lung tumors that arise in smaller, peripheral bronchi. They give rise to a rather indefinite group of symptoms, have a characteristic x-ray picture and are rather easily confused with solitary metastatic tumors, and infections in the lung. This type of tumor may also simulate mediastinal and chest wall neoplasms. These solitary, circumscribed lung tumors constitute about 25 per cent of all primary lung tumors. Included in this discussion are 23 patients seen at the University of Chicago Clinics in the past 10 years with a solitary, rounded lesion in the lung that was at least 2 inches in diameter and at some time in the course of the illness was considered to be a neoplasm. We have included only patients in whom microscopic proof of the diagnosis was obtained, or those in whom certain clinical features make the diagnosis fairly certain.

The characteristic x-ray appearance of these lesions is a solitary, rounded, dense mass in the lung. Usually the borders of the tumor are very sharp, but this feature may be obscured by the proximity of the lesion to the mediastinum or chest wall. Occasionally a cavity within the tumor (Fig. 2) is visualized (5, 7).

The symptoms in this type of lung tumor are varied. Table I contains the chief complaint of the 23 patients in this series. The most striking features demonstrated are the lack of cough and the relative infrequency with which the presenting complaint gave the clue that the primary pathology was in the lung. In 6 of the group there was no obvious complaint. Pain in the chest was most commonly present, but was seen in less than one-third of the patients and probably occurred late in the course of the disease. Cough was the main complaint in only 5 patients, 2 of whom had cavitary carcinomas. Four patients had marked weight loss and 1 presented himself because of clubbing of the fingers. Table II listing the more common symptoms illustrates the same points. In addition it shows that the symptoms of advanced disease (viz. weight loss, weakness, and anorexia) were very prominent features. Only 5 patients in the entire series had hemoptysis. It is interesting that 5 individuals noticed clubbing of their fingers. Also it is worthy of note that 3 patients had an illness diagnosed as pneumonia in the course of their disease, despite the fact that the lesion was circumscribed and in the periphery. Further evidence of the variable nature of the onset of the disease is that only 11 of the 23 patients were admitted to the medical or surgical chest clinics.

Physical findings can best be dismissed with the statement that they were extremely variable and often absent. About half of the patients had abnormal findings in the chest, but in none were the findings diagnostic. The main value of physical examination in this type of case is to find metastases from a primary lung cancer, or a primary tumor elsewhere, which is responsible for a metastasis to the lung.

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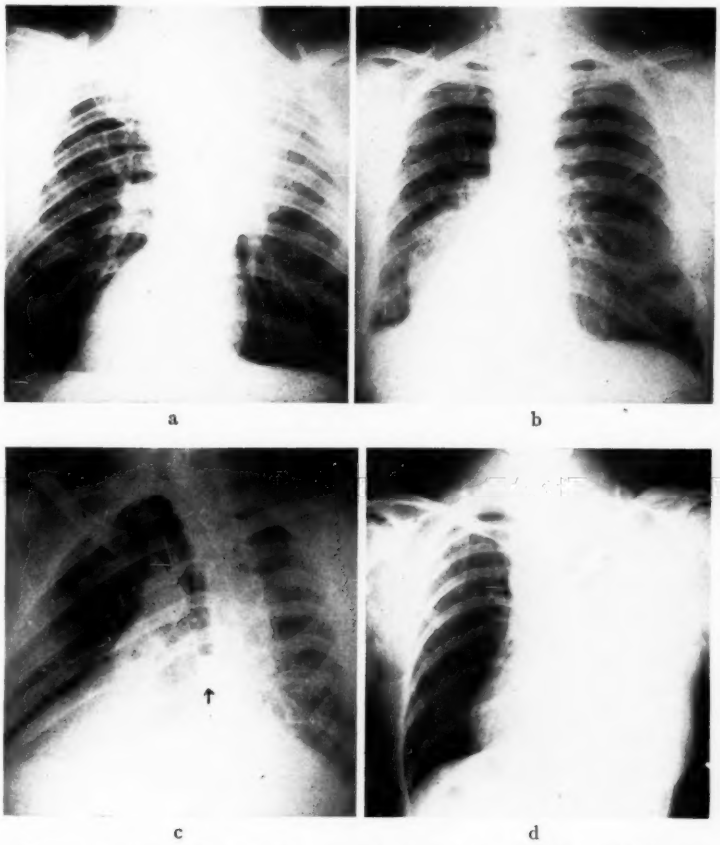

Fig. 1. A series of chest roentgenograms to show the stages of bronchial obstruction in cancer of the lung. a, X-ray film of the chest demonstrating the most common roentgenologic finding in bronchogenic carcinoma; viz., a diffuse, irregular area of atelectasis in the right upper lung field. b, Collapse of the left lower lung lobe with a triangular shadow near the heart in a patient with a squamous cell carcinoma arising in the bronchus of the left lobe. c, Iodized oil injection of the tracheobronchial tree, localizing obstruction in the right middle and lower lobe bronchi. Arrow points to the puddling of oil. d, Roentgenograms of the chest in an individual with complete collapse and infiltration of the right lung due to bronchogenic carcinoma. Clinically and at autopsy there was no fluid in the pleural space.

Table III lists the diagnoses in this group of patients. Seventeen of the 23 rounded opacities demonstrated on x-ray examination were malignant lung tumors. Only 3 were metastatic; 14 were primary in the lung. One patient had a benign lung tumor. Such a tabulation emphasizes 3 important points. First, so called cannon-ball tumors of the lung, if seen as solitary lesions, are most likely primary in the lung. Second, metastatic tumors to the lung are usually multiple when demonstrated clinically. About 30 multiple metastatic tumors of the lung are seen at this clinic yearly (10) but in the past 10 years only 3 solitary metastases to the lung have been definitely demonstrated. Third, highly differentiated neoplasms were relatively common among the primary lung tumors. There was only 1 sarcoma and 4 undifferentiated carcinomas. One patient with a squamous cell

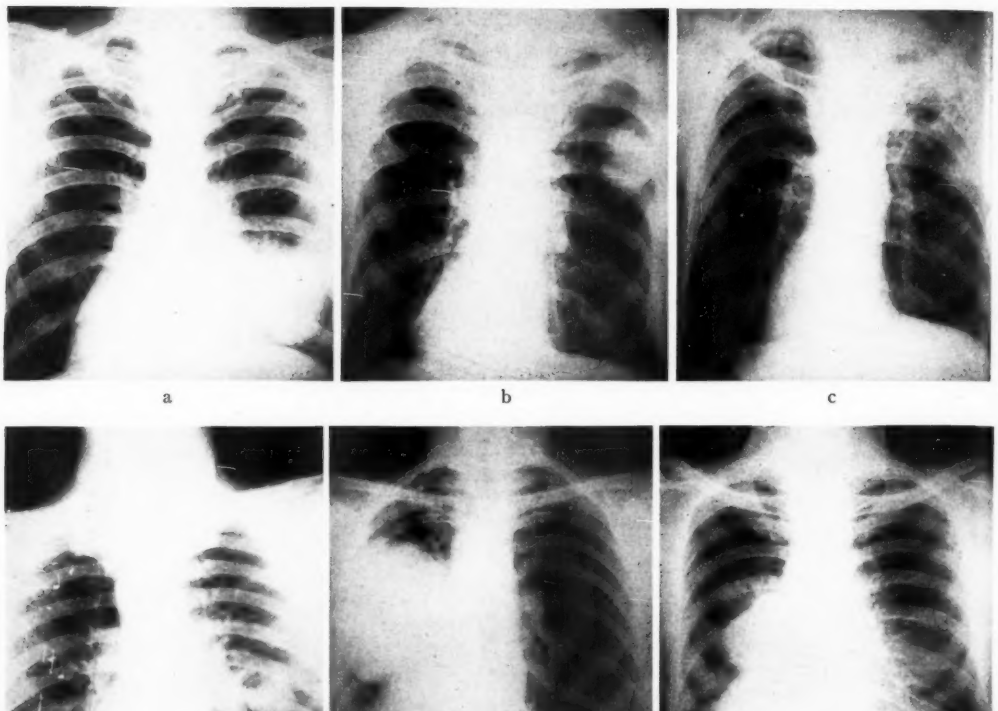

Fig. 2. A series of circumscribed tumors primary within the lung. a, Primary adenocarcinoma in the base of the right lung. b, Primary squamous cell carcinoma in the right upper lung field. This lesion had been followed 3 years when this film was taken. c, Cavitary lesion in the right apex simulating tuberculosis. This was a primary bronchogenic carcinoma. d, Cavitary carcinoma of the right lower lobe. e, Large malignant epidermoid, that shelled out of the lung field much like a cyst. However, the patient later died of recurrence. f, Sarcoma of lung simulating a mediastinal tumor. At operation there were widespread metastases throughout the left pleural space.

carcinoma was followed 3 years before an operation was done to remove the tumor.

The most common error made in this series was in the diagnosis of tuberculosis. Two patients were operated on for a solitary circumscribed lesion which was later found to be a tuberculoma; in another 2 patients we were able to make the clinical diagnosis of tuberculoma because of calcium deposits in the lesion. One patient had a chronic lung abscess that could not be differentiated from tumor before operation.

It is obvious from our discussion that at times we had considerable difficulty in arriving at a logical preoperative or antemortem diagnosis. We have already indicated that the clinical history and physical examination were of less aid than is usually the case in diseases of the chest. The age of the patient was of some value after the presence of an obvious lesion in the lung was ascertained.

Fluoroscopic and x-ray examinations demonstrated every tumor in the series and gave some clues as to the type of the lesion. Calcification within the lesions indicated tuberculosis. Position within the chest with respect to the anteroposterior diameter localized some lesions within the mediastinum. Sputum

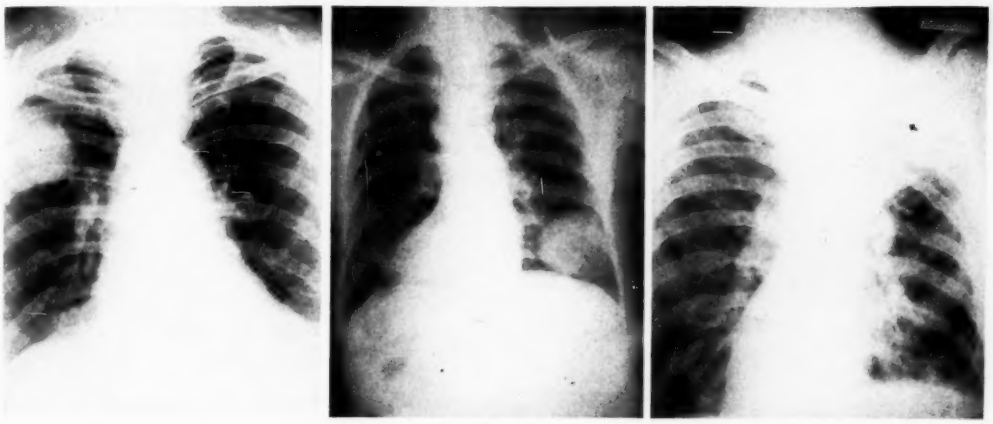

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Fig. 3. Circumscribed lesions that were not primary lung cancers. a, Tuberculosis of the right upper lobe which was resected before a diagnosis could be definitely established. b, Metastatic sarcoma from the uterus, diagnosis substantiated at autopsy. c, Cavitary lesion in the right apex (see arrow) that could be tuberculosis or tumor. This was a chronic pyogenic lung abscess that healed following drainage.

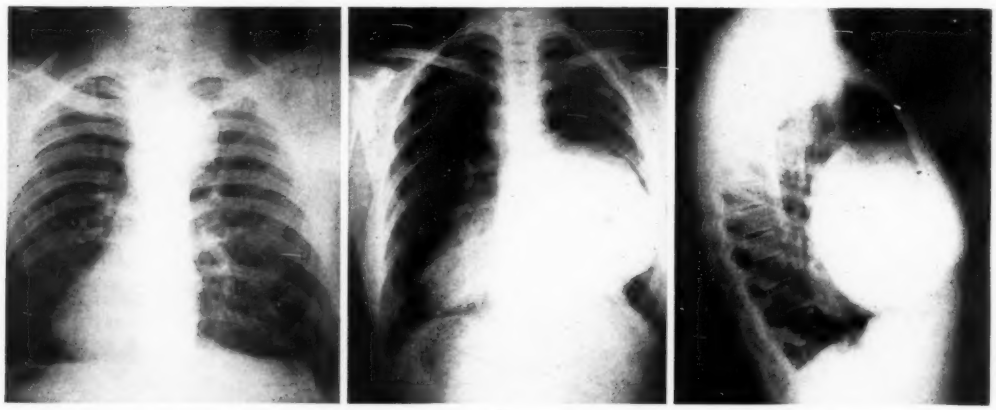
examinations were made routinely. Cultures and examination for tubercle bacilli were done; however, in none of the 4 cases of tuberculosis were tubercle bacilli demonstrated, and no specific organism was found in the patient with a chronic lung abscess. Guinea pig inoculation of the sputum was positive in 1 case. Microscopic sections of the sputum to detect tumor cells was occasionally done but was not conclusive.

Bronchography was done in several patients and was often a distinct aid in localizing the lesion within the lung, in contrast to mediastinal lesions. Bronchoscopy was done in 12 patients, but in only 2 was a positive biopsy obtained. Examination of the pleural fluid (none present), aspiration biopsy, diagnostic pneumothorax, and thoracoscopy were not done in this group of patients.

In view of the difficulty of diagnosis in this type of case it is interesting to review the procedures that actually led to the correct diagnosis (Table IV). In 4 patients the diagnosis was made on the basis of history, physical findings, and x-ray examination. Two of these were patients who demonstrated calcium in asymptomatic lesions. A diagnosis of tuberculosis was made, and the clinical course of the patients substantiated this impression. The third patient had a hypernephroma of the kidney. No histological preparation was made of the lung lesion, but since the patient died soon after it appeared, it almost surely was metastatic from the kidney. The fourth patient had a benign lung tumor (hemangioma) that was suspected on the basis of polycythemia, cyanosis, and clubbing of the fingers and toes, in the absence of heart disease and pulmonary fibrosis. This diagnosis was substantiated at operation.

In 2 patients with lung cancers a positive biopsy was obtained at bronchoscopy. These 2 patients and the 4 here described were the only ones in which we could be absolutely sure of the diagnosis before operation or autopsy, although in many of the cases the correct diagnosis was suspected. In 7 patients the diagnosis was made at autopsy. In 5 of this group the diagnosis was considered during life, but in 2 the lung tumor was unsuspected before autopsy. In 10 individuals a diagnosis of probable lung tumor was made and exploration of the chest was done. In this group there were 5 primary carcinomas of the lung, 2 tuberculomas, and 1 each of chronic lung abscess, sarcoma, and malignant epidermoid.

The almost complete failure of our usual aids to make an accurate diagnosis in these cases suggests very strongly the use of early exploratory thoracotomy as a diagnostic pro-



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d e f

Fig. 4. Mediastinal tumors that could be confused with primary lung tumors. a, Bronchial cyst of the superior mediastinum removed at operation. b, Dermoid of the anterior mediastinum. c, Lateral view of b to show the anterior position of the tumor. d, Aneurysm of the aorta that was diagnosed by calcification (arrow) in its wall. e, Mediastinal abscess (tuberculous) that could not be diagnosed before exploration of the chest. f, Neurofibroma of the mediastinum placed far posteriorly in the vertebral gutter.

cedure. When properly done, a thoracotomy carries as little morbidity and mortality as exploratory laparotomy. Since our figures show that most of these lesions will be primary lung cancers, surgical treatment at the earliest possible date is the procedure of choice. Actually, removal of a solitary metastatic lesion in the lung may be reasonable when the primary tumor is also resectable (1, 2, 8). Excision of solitary tuberculomas gives very favorable results (3, 4, 9). If a chronic pyogenic infection in the lung is found the incision is closed and local drainage done at a later date when the pleura becomes obliterated.

DIFFERENTIAL DIAGNOSIS

Primary tumors of the lung in general can usually be differentiated from metastatic tumors at bronchoscopy (6). The primary tumor arising within the bronchus is usually easily subjected to biopsy, but metastatic tumors occur in the parenchyma and are not visible on bronchoscopy. However, the lesions in this series arose far out in the lung and even when primary in the lung very few could be seen through the bronchoscope. Actually, about the only way to diagnose a metastatic tumor was to find the primary lesion.

TABLE I.—PRESENTING COMPLAINTS WHEN FIRST SEEN IN THE OUT CLINIC

Complaints	No.
Pain in chest	7
None	6
Cough (productive)	5
Weight loss	4
Clubbing of fingers	1
Total cases	23

TABLE II.—MOST COMMON SYMPTOMS IN THIS SERIES

Symptoms	No.	Symptoms	No.
Weight loss	12	Pneumonia	3
Cough	10	Bone pain	2
Chest pain	10	Asthma	1
Weakness	8	Cyanosis	
Anorexia	6	Hematuria	
Hemoptysis	5	Coma	
Clubbing fingers	5		

Circumscribed tumors can often be distinguished from solitary tuberculous lesions. In some cases of tuberculosis, there will be other evidence of acid-fast infection in the lung fields or calcification within the lesion itself. Calcification is never seen in a malignant lung tumor, although it may be present in benign lung tumors. If a positive sputum can be obtained, the diagnosis is obvious although both neoplastic and tuberculous lesions may coexist.

A word of caution is in order regarding the presence of cavitation in the absence of acid-fast bacilli. Practically all tuberculous cavities of any size will produce a positive sputum unless they are the so called "closed" cavities. If a cavity is demonstrated and no tubercle bacilli are found, a neoplasm must be strongly suspected. If no tumor is found at bronchoscopy and acid-fast bacilli are absent in the sputum, the diagnosis of a primary pyogenic infection in these cavitary lesions is usually made by exclusion. Although cultures are made, they seldom lead to the correct diagnosis. Most often these chronic lung abscesses, in the absence of a definite history, can be diagnosed only by biopsy at thoracotomy.

Mediastinal lesions offer the greatest problems in differential diagnosis and although it is possible to diagnose a tumor of the mediastinum before operation in many cases, in at least half of the patients seen, it is necessary to explore the lesion to make an accurate diagnosis. Tumors of the anterior mediastinum usually offer little difficulty. Dermoids may attain a large size before they are seen, and a lateral film of the chest showing the lesion placed far anteriorally is usually sufficient to make the diagnosis. Substernal thyroid can often be demonstrated to have a connection with the thyroid gland in the neck and they may be associated with signs of toxicity. In the midportion of the mediastinum the most common lesion is one type of the lymphomas. Only rarely do these lesions assume a circumscribed solitary appearance, although occasionally such a lesion may give rise to considerable confusion in the diagnosis. Aneurysms occasionally will have calcification in their walls and most often the symptoms and findings of associated cardiac or vascular disease will lead to the correct diagnosis. Expansile pulsations will also prove the diagnosis if the blood in the aneurysm is not clotted. Bronchogenic and gastric cysts from their x-ray appearance alone may exactly duplicate primary lung tumors, but they usually occur in a patient who has no symptoms and who seems to be in good health. Low-grade mediastinal abscesses, unless they connect with the bronchus to produce symptoms, usually cannot be distinguished from primary lung tumors. Metastatic tumors

TABLE III.—FINAL DIAGNOSIS[1]

Diagnosis	No. patients	Diagnosis	No. patients
Primary lung tumor	(15)	Metastatic lung tumors	(3)
Squamous cell carcinoma	4	From kidney	2
Adenocarcinoma	4	From uterus	1
Carcinoma (untyped)	4	Tuberculosis	(4)
Sarcoma	1	Chronic lung abscess	(1)
Malignant epidermoid?	1		
Hemangioma	1		

[1]Ascertained by operation, autopsy, bronchoscopy, or the clinical course of the patient.

TABLE IV.—METHODS USED TO ESTABLISH DIAGNOSIS IN OUR SERIES

Method		No. patients
Exploratory thoracotomy		10
Autopsy		7
a. Suspected clinically	5	
b. Unsuspected	2	
Clinical characteristics		4
Bronchoscopy		2

from bone, breast, testes, and kidney to the midportion of the mediastinum are correctly diagnosed by having knowledge of the primary lesion. Neurofibroma in the posterior mediastinum can easily be distinguished by fluoroscopy or a lateral x-ray picture showing the lesion placed far posteriorly in the vertebral gutter.

Finally, chest wall tumors give rise to very little difficulty in differential diagnosis. They most often show evidence of rib destruction, calcification within the lesion, or are palpable externally.

TREATMENT AND RESULTS

Some statement probably should be made as to the treatment and final outcome in these patients. There were 4 instances of primary squamous cell carcinoma in the lung. One patient died 2 weeks following operation of cardiac failure after a seemingly successful removal of the tumor. Two patients were explored and found to be inoperable and are now deceased. One individual survived a pneumonectomy 1 year ago and is now well. Two of the 4 patients with adenocarcinomas received x-ray therapy and are now deceased. One patient had a successful pneumonectomy 10 months ago and is well without evidence of recurrence. One patient died of recurrence following lobectomy. All 4 patients with untyped carcinomas were explored and found to be inoperable. They died within a year after operation. The patient with the sarcoma was explored and found to be inoperable. X-ray therapy was given but the man died. The malignant epidermoid was successfully resected, but the patient died about 10 months later of recurrence. The 1 benign tumor (hemangioma) survived a pneumonectomy 6 months ago and is seemingly cured. All 3 patients with metastatic tumors are deceased. The 4 patients with tuberculosis are alive and all but 1 are considered well. The patient with a chronic pyogenic lung abscess is entirely asymptomatic.

SUMMARY AND CONCLUSIONS

1. A group of 23 patients with solitary circumscribed opacities in the lung have been presented.

2. These lesions are characterized by indefinite symptoms and physical findings, and failure of the usual diagnostic aids to establish the correct diagnosis.

3. In our experience exploratory thoracotomy was the surest method by which an accurate diagnosis could be made and this procedure is recommended as an early diagnostic aid, because it leads to early treatment.

4. Occasionally circumscribed opacities in the lung are tuberculomas or chronic lung abscesses, but most often they are primary lung cancers.

5. Solitary metastatic tumors of the lungs are relatively rare.

6. Methods of differential diagnosis, particularly from mediastinal and chest wall tumors, are discussed.

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PYOGENIC COXITIS

I. End-Results and Considerations of Diagnosis and Treatment

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DURING the past few years, the authors have seen so many fortunate results following pyogenic infection of the hip that it has been difficult to reconcile them with the general pessimistic attitude recorded in the medical literature. In acute cases, suppuration often has been followed in our experience by a stable and painless hip, and motion has just as frequently been preserved, especially when early and careful treatment has been applied. We have, therefore, analyzed the end-results of 132 cases[1] available to us with a view of determining the factors that would lead to the best functional results following suppuration in the hip joint. In the course of this study, it became apparent that one of the most important factors was age. The hip joint reacts differently to pyogenic infection, depending upon the amount of cartilage present in the hip. This, in turn, is a function of age. The bearing on long term end-results of the controversial points of hip joint drainage and methods of after-care by plaster or traction has never been accurately evaluated. It is of importance to try to determine the factors which will lead to a desirable end-result: be it a stable hip secured by bony ankylosis in good position or a movable hip with restricted motion, stabilized by the remaining portion of the femoral head and neck. The methods aimed at securing the latter result, which is ideal, should receive attention both in the acute stage and in later stages when suppuration has long since subsided. An unstable hip, by which we mean both the type where structural support has been lost and the type rendered unstable in unilateral weight-bearing by muscular dysfunction (Trendelenburg test), is unsatisfactory, since it produces an unsightly gait, even when both lower extremities are of equal length. Most of the literature dealing with acute and chronic pyogenic infections of hip joints is of little value in analyzing end-results because of the lack of accurate and detailed case reports and because no follow-up is available.

Bergmann, in reviewing the subject of osteomyelitis of the pelvis, recognized the chronicity and disability that followed perforation of infection into the hip joint as a complication of osteomyelitis of this region. Monsaingeon and Peeremans recognized pyogenic hip involvement complicating osteomyelitis of the ilium and stated that ankylosis was always due to this complication. Klem, in his monograph on osteomyelitis, found suppurative coxitis in 15.2 per cent of all his cases and ascribed chronicity to the deep lying bone suppuration. Moulonguet first described the radiological alterations of diffuse joint space loss in acute hip infections of synovial type and pointed out that dislocation was most often due to loss of femoral bone.

Kortzeborn and Hesse reported upon acute suppurative arthritis. They came to the conclusion that arthrotomy of itself condemned a joint to ankylosis and also reported a high mortality. Nathan reviewed his experience with over 200 cases of acute and chronic osteomyelitis of the upper femur involving the hip joint. His conclusions, while important, are not without exception. This author believed it necessary to open surgically every hip joint in which suppurative products were found and that every metastatic hip joint in-

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[1]We have also inspected the roentgenograms or studied the records of 177 additional cases that became available after compilation of the statistical division of this study. Those cases add nothing to the facts and conclusions drawn from the original number of cases.

TABLE I.—SEX AND AGE GROUPS OF 132 PATIENTS WITH SUPPURATIVE COXITIS

Age of onset	Males	Females	Totals
0–3 years	10	10	20
4–12 years	37	32	69
Adolescents and adults	29	14	43
Totals	76	56	132

fection was traceable to metaphyseal or epiphyseal bone infection. He believed streptococcus infection to differ radically from staphylococcus involvement, both in prognosis and chronicity. As will be pointed out in a later section of this paper, the extent of bone killed by the embolic process and the tendency toward dislocation of the femur determine the prognosis and chronicity. This author painted an unnecessarily black picture of the outlook in staphylococcus bone suppuration stating that massive bone necrosis and sequestration invariably resulted in recurrence and chronic suppuration. Inge and Liebolt reviewed the literature on the treatment of acute suppurative arthritis and reported on the late results in 36 cases treated by operation in the New York Orthopedic Hospital from 1918 to 1933. They emphasized prompt arthrotomy with drainage, traction, and passive and active motion as most likely to produce a joint resembling the normal. Relatively few (4 of 20) acute suppurating hip joints subsequently became stiff under such a regimen. They did not study end-results of stability of this joint in relation to bone destruction.

Blake, Reich, and Caldwell reviewed joint suppuration and gave a bibliography. The latter two authors emphasized the now well known relations of the hip joint capsule to the metaphyseal centers about the hip. These will not be described here except to give the details of age variations and to point out that septic emboli lodging about the hip invariably lie within the joint except at the periphery of the enchondrial zone of ossification for the greater trochanter and in the pelvic bones at a certain distance from the juxta-acetabular zone. These anatomic facts explain the occurrence of certain rare forms of osteomyelitis that occur near the hip but which do not involve the joint. Caldwell believed that the lack of bone infection often leads to a good functional result but ankylosis or pathological dislocation resulted when bone was involved.

Slowick and Badgley and his associates have reported the largest series recently, respectively 60 and 113 cases of septic hips. Slowick pointed out for the first time that acute purulent infections of the hip joint in infancy should be separated from those of childhood and adult life. The former, as a group, have shown early healing and freedom from recurrence, sequestration of bone, and severe joint destruction. Both authors noted the favorable prognosis with early drainage, traction, and other diligent after-care methods.

Slowick believed that bone involvement was never associated with streptococcus infection. About half of his group of patients recovered with a stable hip, the number being equal in the streptococcus and the staphylococcus groups. Badgley's study was a comprehensive analysis of 113 cases with attention to end-results in terms of age, the causative organism, the amount of bone involved and sequestrated, drainage, and the types of postoperative treatment employed. That most of the grave complications which have hitherto been associated with this condition are preventable was stressed by Badgley and will be substantiated later in this paper.

TABLE II.—SEX CORRELATED WITH INITIAL POINT OF INVOLVEMENT IN 147 SUPPURATIVE HIPS

	Age of onset			Totals	Initial lesion				
	0–3	4–12	Adolescents and adults		Synovia	Femur	Ilium	Ischium	Unknown
Males	11	44	32	87	10	25	18	1	33
Females	11	34	15	60	7	20	12	1	20
Totals	22	78	47	147	17	45	30	2	53

The fundamental work of Phemister showing that cartilage undergoes ready solution in a pyogenic exudate should be mentioned, since this mechanism produces the early termination and benign course of the suppurative arthritis of infancy which often results in prompt dislocation of the hip. He also demonstrated that pressure accelerated cartilage destruction in the presence of a pyogenic exudate. Traction combats cartilage and joint destruction by removing the pressure of joint surfaces, while drainage prevents excess accumulation of purulent material.

The incidence of suppurative coxitis can only be estimated. Of 1,041 admissions for pyogenic osteomyelitis seen at the University of Chicago Clinic among 210,000 patients in 11 years, 107 pyogenic hips were encountered in 94 cases. Among the first 3,000 orthopedic cases beneath the age of 21 years seen in the clinics of the Division for Handicapped Children of the Illinois State Department of Public Welfare, 40 ancient septic hips were found in 38 disabled children. In a census of crippled and deformed children in the State of Illinois made by the same agency, 195 cases of this disorder were encountered among 27,000 crippled children beneath the age of 21 years (0.74 per cent incidence among crippled children). These estimates are abnormally weighted with chronic cases and cases originating from widespread osteomyelitis, since the general surgeon usually sees the patients of the acute group of cases. The sex and age groups of the patients represented in this series of cases are given in Table I. The initial point of involvement, correlated with sex and age groups is given in Tables II and III. Males are more frequently involved than females, just as is the case in pyogenic osteomyelitis. In 94 of our cases in which the initial lesion could be determined accurately from a study of serial roentgenograms, an osteomyelitis focus could be demonstrated in the majority of cases (81.9 per cent). This is due to two factors: The probable greater number of chronic cases in which the history was subsequently traced back to the beginning of illness and the long time follow-up by serial roentgenograms of our acute cases. The follow-up period, and the frequency of observation during it, have not been uniform in this present series of cases, but more than two-thirds of the cases have been followed more than 10 years. Such a period provides

TABLE III.—AGE AND INITIAL FOCUS OF SUPPURATION

Initial lesion	Age of onset			Totals
	0–3	4–12	Adolescents and adults	
Synovia	2	6	9	17
Femur	10	25	10	45
Ilium	2	14	14	30
Ischium	0	0	2	2
Unknown	7	35	11	53
Totals	21	80	46	147

TABLE IV.—ORIGIN OF INFECTION IN SUPPURATIVE COXITIS ACCORDING TO AGE AND INITIAL LESION

Source of infection	Age of onset			Totals	Initial lesion				
	0–3	4–12	Adolescents and adults		Synovia	Femur	Ilium	Ischium	Unknown
Skin	1	14	11	26	2	5	8	0	11
Upper respiratory tract	5	9	2	16	5	2	0	0	9
Ear	3	12	2	17	5	6	2	0	4
Genitourinary tract	0	0	4	4	1	0	1	1	1
Osteomyelitis, elsewhere	0	3	2	5	0	4	0	0	1
Direct infection	0	0	1	1	1	0	0	0	0
Unknown	13	40	25	78	3	28	19	1	27
Totals	22	78	47	147	17	45	30	2	53

TABLE V.—CAUSATIVE ORGANISMS IN SUPPURATIVE COXITIS

	Age of onset			Totals
	0–3	4–12	Adolescents and adults	
Staphylococcus aureus	0	15	16	31
Staphylococcus albus	0	1	0	1
Streptococcus hemolyticus (β)	6	10	2	18
Pneumococcus type III	0	0	1	1
Unknown	16	52	28	96
Totals	22	78	47	147

observations of end-results that for the most part are stationary.

ETIOLOGY, SYMPTOMS, AND EARLY DIAGNOSIS INCLUDING ROENTGEN FINDINGS

Infection of the hip and surrounding structures in this series of cases has occurred almost without exception through the blood stream. Infection by penetrating wounds is not frequently encountered, since this is a deep lying joint. The origin of pyogenic organisms has been the usual origin of infection in pyogenic osteomyelitis (Table IV). In 69 hips, data for which were available, the origin of bacteria was from the upper respiratory tract including the mastoid process and the middle ear, or from the skin in the majority of cases. Causative micro-organisms are given in Table V. The gonococcus was implicated by inference in only a few cases, possibly because fewer cultures were available in older persons, which group was in the minority in this series. Usually our patients were in good general condition prior to the onset of the illness under discussion. An acute illness, symptomatic of the septicemia or bacteriemia usually ushered in the disease. An insidious course more rarely obtained.

It should be pointed out here that the hip joint is unique; it is bordered at least by four metaphyseal zones, all of which are definitely intracapsular. This includes the capital femoral epiphysis and the three pelvic metaphyses underlying the articular cartilage of the acetabulum in the ilium, ischium, and pubis. The exact relationship of these end-artery zones and the epiphyseal and joint cartilages, varying with age, will be described separately later in this paper. Existing statistics on bone growth point out that 12 per cent of the longitudinal growth of the long bones of the lower extremity occurs from the upper femoral epiphysis. Doubt is cast on the inflexibility of these estimates as applied to this condition. The modification of the architecture of bone about the hip by infection which, in turn, is the key to hip stability, is the most important factor in determining the final result. Variations will be described in the discussions dealing with each age group. Many factors influence the amount of bone remaining in the quiescent stage. These include the extent of original embolism and the type of treatment employed, especially its efficiency in preventing dislocation, pressure within the joint, and further loss of bone by pressure and pathological fracture. These latter factors are under complete control of the surgeon.

The diagnosis of suppuration in the hip joint is often apparent from the occurrence of pain, muscle spasm about the hip, and the physical findings of flexion and external rotation with or without abduction or adduction. When this condition occurs as part of multiple bone and joint suppuration, the local symptoms and signs are often inconspicuous and the diagnosis missed, delayed, or discovered accidentally by roentgenograms. The localization of the pain is occasionally misleading depending upon the acuteness and location of the initial osseous lesions about the hip and those elsewhere. Referred pain in the thigh or knee may direct the attention of the unwary diagnostician away from the hip. In the chronic cases, the patient comes to the surgeon because he has a locomotor difficulty following an acute illness.

Aspiration of the hip joint with or without arthrotomy is the only method of establishing the diagnosis in doubtful cases and is confirmatory in typical cases. It should be done early in all suspected cases. Seropurulent or frankly purulent material is obtained depending upon the duration of suppuration and the causative organism. Occasionally fluid is found which is typical of joint exudation and which is sterile on culture. This results when the bone infection borders upon the joint but

TABLE VI.—END-RESULTS OF CHANGES ABOUT THE HIP RELATED TO THE INITIAL LESION OF SUPPURATIVE COXITIS

		Initial lesion				
		Synovia	Femur	Ilium	Ischium	Unknown
Dislocation	None	13	21	21	2	23
	Partial	1	7	2	0	6
	Total dislocation	3	17	7	0	24
	Totals	17	45	30	2	53
Loss of head	None	11	6	12	2	5
	Partial	3	14	15	0	17
	Total	3	24	3	0	31
	Unknown	0	1	0	0	0
	Totals	17	45	30	2	53
Loss of neck	None	17	13	26	2	13
	Partial	0	23	3	0	29
	Total	0	7	1	0	11
	Unknown	0	2	0	0	0
	Totals	17	45	30	2	53
Clinical shortening	0–2 cm.	7	8	15	2	12
	2–4 cm.	3	7	7	0	7
	4–6 cm.	0	7	1	0	10
	6 plus	0	7	0	0	13
	Unknown	7	16	7	0	11
	Totals	17	45	30	2	53
Shortening due to bone loss	Equal	10	17	22	2	27
	Unequal	0	4	1	0	3
	Unknown	7	24	7	0	23
	Totals	17	45	30	2	53
Stability	Stable	17	28	26	2	42
	Unstable	0	12	3	0	11
	Unknown	0	5	1	0	0
	Totals	17	45	30	2	53
Motion	Good	5	22	8	2	18
	Poor	5	3	8	0	8
	Fused	7	16	10	0	27
	Unknown	0	4	4	0	0
	Totals	17	45	30	2	53
Proximal femoral epiphysis	Closed	5	31	8	0	29
	Not closed	11	13	21	2	17
	Unknown	1	1	1	0	7
	Totals	17	45	30	2	53
Y. Cartilage	Closed	6	26	8	0	26
	Not closed	9	16	21	2	20
	Unknown	2	3	1	0	7
	Totals	17	45	30	2	53

TABLE VII.—ARTHROTOMY AND POSTOPERATIVE TREATMENT IN SUPPURATIVE COXITIS

	Age of onset			
	0–3	4–12	Adolescents and adults	Totals
Arthrotomy for drainage				
Early	15	45	25	85
None	3	7	13	23
Late	1	16	8	25
Unknown	3	10	1	14
Totals	22	78	47	147
Postoperative traction				
Early	5	17	12	34
None	8	19	14	41
Inadequate	2	1	0	3
Late	1	4	4	9
Unknown	5	28	12	45
Cast	1	9	5	15
Totals	22	78	47	147

has not involved it. Aspiration should be repeated if pus is not readily obtained when symptoms and signs suggest a pathological condition in this joint. It should be constantly borne in mind that diagnosis by aspiration is often possible many days and weeks before roentgenograms show a bone focus. Occasionally one or two aspirations will be curative, but in the majority of cases, it is wiser to open the joint after aspiration has established the diagnosis, if temperature and local muscle spasm do not immediately

TABLE IX.—BACTERIOLOGICAL FINDINGS RELATED TO HIP DISLOCATION AND MOTION AT THE HIP

	Motion			
	Good	Poor	Fused	Unknown
Micro-organism				
Staphylococcus aureus	7	7	13	4
β-hemolytic streptococcus	10	2	4	2
Totals	17	9	17	6
Dislocation				
Total	24	11	17	4
Partial	9	0	7	0
None	21	13	37	4
Totals	54	24	61	8

TABLE VIII.—HIP STABILITY PRODUCED BY ADEQUATE DRAINAGE AND EXTENSION

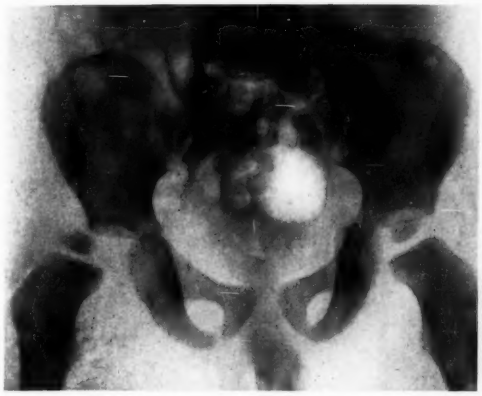
	Stable	Unstable	Unknown	Totals
Adequate drainage and traction	25	0	3	28
Inadequate treatment	55	15	2	72
Type of treatment unknown	39	8	0	47
Totals	119	23	5	147

subside. In chronic cases with minor symptoms, the patient may require only traction after the diagnosis has been established by aspiration. The criterion of sufficiently prolonged traction is maintenance of joint space and position after its removal (Fig. 1).

While it usually is considered that there are no alterations to be demonstrated by roentgenograms until 7 to 14 days after onset of illness, this initial period may be prolonged to two months in those cases in which there is a small periacetabular focus. On the other hand, by the second or third day of the acute illness, there may be roentgen signs of dislocation manifest by lateral displacement of the hip from the acetabulum. This early roent-

TABLE X.—LOSS OF LEG LENGTH IN SUPPURATIVE COXITIS DUE TO OSSEOUS DESTRUCTION AND DISLOCATION OCCURRING IN INFANTS AS OBSERVED MANY YEARS LATER

Patient	Age at onset	Time from onset to present observation	Clinical leg length discrepancy	Loss of bone or dislocation or both as measured in roentgenograms (median value 4.0 cm.)
M. B.	6 wks.	8 yrs.	7 cm.	6.5 cm. (head and neck)
J. G.	6 mos.	9 yrs.	3 cm.	3.0 cm. (head, neck and dislocation)
R. E.	6 mos.	8 yrs.	6.5 cm.	2.0 cm. (head and neck)
R. G.	2 yrs.	6 yrs.	3.5 cm.	2.0 cm. (head)
D. P.	2 yrs.	10 yrs.	4.0 cm.	3.0 cm. (head and dislocation)
A. Z.	2.5 yrs.	16 yrs.	9.0 cm.	4.0 cm. (dislocation)
F. S.	1.25 yrs.	13 yrs.	4.5 cm.	4.5 cm. (head and neck)
O. C.	4 wks.	14 yrs.	5.0 cm.	4.0 cm. (head and dislocation)
J. F.	2 yrs.	10 yrs.	7.0 cm.	6.0 cm. (head and dislocation)
R. D.	3 wks.	12 yrs.	4.0 cm.	4.0 cm. (dislocation)
D. S.	15 mos.	3.5 yrs.	3.0 cm.	3.0 cm. (dislocation)
F. B.	3 wks.	12 yrs.	4.0 cm.	4.0 cm. (dislocation)
B. B.	2 mos.	15 yrs.	5.0 cm.	5.0 cm. (head and dislocation)
M. H.	11 mos.	12 yrs.	4.0 cm.	4.0 cm. (dislocation)



a

b

c

Fig. 1. Illustrates early diagnostic changes of suppurative coxitis in roentgenograms with end-results. Case 1, R. D., age 10 months at onset. a, Early roentgenographic findings showing bilateral dislocation of the hips prior to appearance of osseous changes—right hip is dislocated laterally and the left hip posteriorly. b, Same case 3½ months later after reduction of both hips and cast immobilization. A small remnant of capital femoral epiphysis remains on the right side. On the left side epiphysiolysis occurred, the roentgenograms at this time showing left metaphysis in contact with acetabular margin. c, Same case, 5⅓ years after onset. Both femurs are united by bone to the acetabulum. A remnant of epiphyseal line is apparent on the right side. Continued growth of moderate degree has been occurring here as evidenced by the levels of the lesser trochanters. However, clinically the legs are of equal length. The patient has an excellent pivoting gait, in view of the disability shown.

genographic sign is the result of accumulation of suppurative products within the joint capsule. There may also be diffuse loss of joint space at a slightly later stage. Underexposed roentgenograms showing soft tissue detail may demonstrate the distended joint space, or the distended joint may be visualized by a contrast medium such as skiodan (Fig. 1). So important are these early signs that roentgenograms should always be taken when the patient is first seen, even though it is far too early to demonstrate a suspected bone focus. Two general courses of this condition can be described: One, when the nature of the disease or the treatment applied does not allow joint distention to develop and dislocation does not occur. Subsequent roentgenograms may then demonstrate diffuse narrowing of the joint space which usually is still occupied by some articular cartilage. If slightly more extensive, this alteration may be followed by surface erosion of the underlying articular bone cortex. When this latter process is completed, it is easy to understand the rapid osseous ankylosis which is then the end-result of this type (Figs. 1, 2, and 6). We believe traction will prevent surface erosion of the bone cortex and allow fibrous tissue to fill in any defects in the articular cartilage. A second type can be described in which the increased intracapsular pressure produces dislocation (Figs. 1 and 2). In these cases, loss of articular cartilage can be inferred only when the bony cortex is eroded, which is then seen in the roentgenogram (Figs. 1 and 2). The loss of bone and shortening due to it are dependent upon the extent of bone involved by infection and the efficacy of traction employed in treatment (Figs. 1, 2, and 6). Late shortening may be the result of closure of the upper femoral epi-

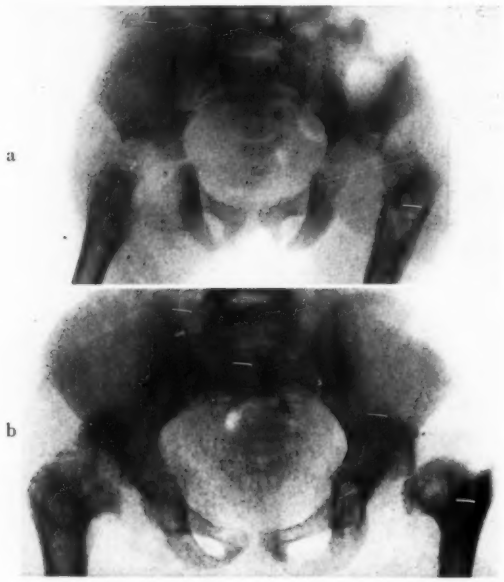


Fig. 2. Bone loss in streptococcus infection of the upper femur involving the hip joint. Illustrations of sequestration of the femoral head. Case 2, J. M., age 22 months at onset. a, Roentgenogram 2 months after onset showing bilateral dislocation of the hips, extensive osteomyelitis of left upper femur and right ilium. Epiphysiolysis has occurred on the left side, and partial destruction of the capital femoral epiphysis has occurred on the right side. This massive bone involvement by β-hemolytic streptococci demonstrates that, on occasion, just as extensive bone involvement can occur with this organism as with the staphylococcus. b, End-result of same case, 2 years later. Both hips have about two-thirds of a normal range of active motion. The right hip is stable in an acetabulum just above the normal one. The left hip is unstable but a significant portion of femoral neck remains.

Fig. 3. Case 3, A. W., age 5 at onset, staphylococcus hemolyticus infection. a, Roentgenogram showing massive osteomyelitis of the upper right femur with necrosis of the head. This head was later removed, and the remaining portion of the neck was placed in the acetabulum. b, Roentgenogram taken 9 months later showing a stable hip. A subsequent clinical examination made nine months still later shows a stable hip and half the normal range of active motion.

physis. Unless dislocation is present, the amount of shortening is usually negligible (Table X, end-results). In both types, bone alterations as seen in roentgenograms are similar but less marked than changes found in osteomyelitis of the long bones.

The causative organism *per se* does not condition the amount of bone destruction (Fig. 2). Extensive osteomyelitis with gross bone loss may result from either β-hemolytic streptococcus or from staphylococcus infection, but usually the extent of bone involvement is less and primary synovial infection more common when streptococci, especially the β-hemolytic variety, are the causative organisms. Joint sequestra of variable size up to the whole femoral head (epiphysiolysis) may result and unless removed become the cause of long continued drainage (Fig. 3). Joint sequestra have previously been described. The diagnosis is more difficult and the indications for treatment less clear-cut in the patient with chronic hip joint disease. Suppuration within the hip is causative of a certain amount of chronic hip joint disease. There is no typical history in these cases, but often the onset of the hip disorder dates from an acute illness. Their complaints are the usual ones associated with disease of the lower extremities: inability to walk or recurrent pain after walking, shortness of the extremity, and difficulty in sitting. When examined, a draining sinus may or may

Fig. 4. Case 4, R. P., age 7 at onset, β-hemolytic streptococcus infection. a, left, Roentgenogram showing necrotic right femoral head, and osteomyelitis of the right femoral neck 5 weeks after onset. Patient was treated by cast immobilization and arthrotomy. b, End-result 1 year after onset showing ankylosed hip with healing of osteomyelitis process. Distortion and collapse of this femoral head have occurred during transformation in the presence of infection.

not be present (Fig. 5). The patient is often unaware of the loss of hip joint motion. Aspiration of the joint in these chronic cases usually does not yield copious fluid but is informative if cultures for bacteria are made. Roentgenograms of the chronic cases show bone destruction (Figs. 2, 3, and 4), and the joint space is usually gone or modified. In extreme cases the "wandering acetabulum" is seen (Fig. 6). Roentgenograms may not be diagnostic, so that arthrotomy or joint puncture is then the only way of establishing a diagnosis (Fig. 7).

When bone involvement is not apparent in early stages of this disease, a study of serial roentgenograms will usually show changes (90.1 per cent of 24 acute cases in this series). Many of these cases would have been termed "synovial infections" if they had not been followed by serial roentgenograms. Small infectious bone foci require weeks and occasionally months to become apparent. It is interesting to note that all acute suppurative hips (7 cases) caused by the β-hemolytic streptococcus were associated with some degree of bone suppuration. The extent of bone suppuration and bone necrosis was definitely less in this group of cases than in those in which the staphylococcus was the causative organism. If drainage of the hip is established under the proper indications, the location of the initial lesion has prognostic significance. If the bone lesion is in the neck of the femur, necrosis of all or part of the femoral head with or without pathologic fracture of the neck is seen. This latter is often prevented by assiduous application of traction (Fig. 8). Statistics relating to end-results, tabulated in terms of the initial location of the suppurative focus are found in Table VI. An inspection of these end-results shows that dislocation occurred most often when there was loss of bone from the femur. Clinical shortening of the more advanced degrees, shortening due to bone loss, hip joint instability, and destruction of the epiphyseal cartilages at the upper femur and at the junction of the ilium, ischium, and pubis (y-cartilage) occurred more frequently and in greater percentage when the femur was involved. The extent of the osteomyelitis focus when it occurs in the ilium is illustrated in Figure 9, showing such data for

Fig. 5. Case 5, O. D., age 19 years at time of roentgenograms. This illustrates a joint sequestrum of a portion of the femoral head. This sequestrum was removed by enlarging an adductor sinus which had persisted since the original infection 7 years previously. Healing promptly occurred.

Fig. 6. Case 6, M. C., 16 years after onset of infection (then aged 37 years). An ancient suppurative hip showing end-result. The joint space is narrowed and the mesial wall of the acetabulum has invaginated (Otto's pelvis). On examination patient had a slight flexion contracture with 90 degrees of active flexion.

35 representative cases. The special causes and prevention of these conditions will be discussed in a later section of this paper.

Initial lesions in the femoral head were not observed in our series, but they are said to occur. Roentgenograms illustrative of septic embolism through the vessels of the ligamentum teres are reproduced in Wilensky's book. When an osteomyelitis focus is in the bones of the pelvis, the joint is spared more often than when the focus is in the neck or upper portion of the femur. Occasionally, however, a bone focus may become established within the femoral neck without involving the hip joint. Tables II and III give the distribution of the foci of suppuration causing hip joint involvement. The point of original involvement can be determined only by inspection of roentgenograms at an early stage in the modification of the bone. Later, it is impossible to be certain of the exact location of the first suppurative focus, due to further bone destruction and to changes produced by pressure and dislocation.

Fig. 7. Case 7, L. W., aged 13 years at onset. The roentgenogram shows an osteomyelitic lesion in the ilium with loss of joint space. An arthrodesis was attempted under the erroneous diagnosis of tuberculosis of the hip. Diagnostic points in favor of pyogenic coxitis: involvement of all surfaces of femoral head, diffuse lesion in ilium consisting of areas of osteolysis and sclerosis, narrowing of the joint space and periosteal new bone.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis of hip joint involvement in the acute stage is usually easy when the signs and symptoms are clear-cut. In the cases with insidious onset and in those that have long since healed with deformity, the differential diagnosis is not always apparent. The following conditions have to be considered: Tuberculosis, Legg-Calvé-Perthes disease, solitary chronic nonspecific arthritis, old slipped upper femoral epiphysis, osteochondritis dissecans of the hip, osteogenic and chondrosarcoma, old congenital dislocation of the hip, aseptic necrosis of the femoral head due to trauma with or without dislocation,

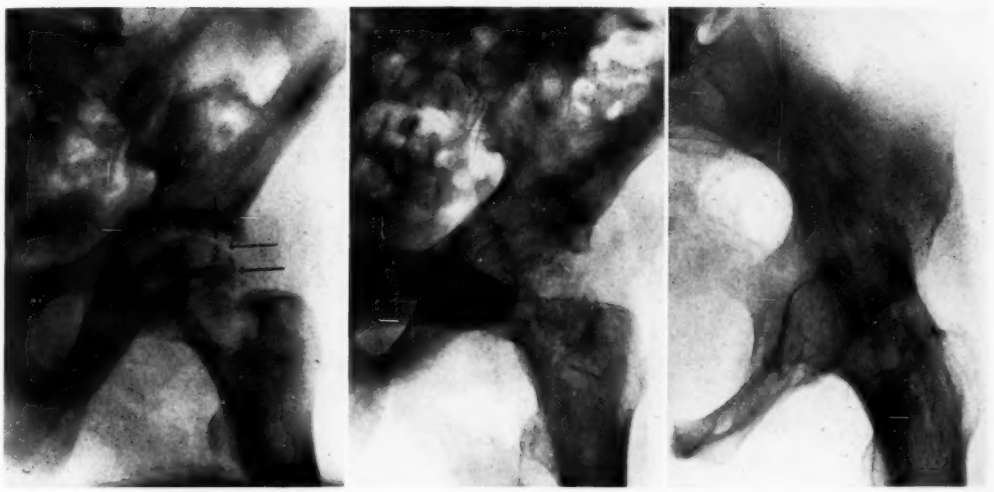


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Fig. 8. Case 8. Preservation of the femoral neck by traction in the presence of embolism of this structure. a, Three weeks after onset showing bone destruction in the upper two-thirds of the femoral neck. Arthrotomy had been performed following joint aspiration two weeks previously; b, 4 months later after removal of the sequestered upper third of the femoral head indicated by arrows in a. Note the new bone bridging the neck defect and filling in the space left by removing the femoral head sequestrum; c, 7½ years after the acute disease. Although the hip is solidly ankylosed and weight-bearing trabeculae are evident, there has been no loss in leg length because fracture was prevented in the acute stage by the application of traction.

metastatic tumors, syphilitic bone involvement and rarer conditions such as hemophilia, idiopathic subperiosteal changes in the newborn, xanthomatosis, fibrocystic disease, neurofibromatosis with bone involvement, caisson disease, echinococcus cysts, and bone islands.

Roentgenograms in tuberculosis of the hip will often suggest the diagnosis since early destruction is marginal or in the metaphysis and unassociated with sclerosis. In adolescents and adults, "kissing sequestra" may be present. The joint space is usually preserved longer in tuberculosis. The Mantoux and other tuberculin reactions are usually positive. The only means of establishing the diagnosis in some cases rests upon tissue examinations and the results of bacterial culture and animal inoculation when the joint is opened (Fig. 7).

The end-results in Legg-Calvé-Perthes disease are typical in roentgenograms: The deformity consists of widening of the femoral neck, flattening of the head with minimal changes in the acetabulum. The end-results of slipped femoral epiphysis are likewise typical, with coxa vara and external rotation of the distal fragment. In chronic nonspecific arthritis there is usually loss of joint space without deformity, to be followed later by marginal hypertrophic changes and sclerosis in the weight-bearing portions. There is often multiple joint involvement in this condition, but the hip joint alone may be affected. In osteochondritis dissecans the point of origin in the articular cortex from which the sequestrum has separated may be identified.

Osteomyelitis of the ilium with or without hip joint involvement has been erroneously diagnosed as osteogenic sarcoma of that bone in chronic cases that subsequently came under our care. One of our cases was referred under this diagnosis, having received extensive roentgen therapy elsewhere. A biopsy with cultures for bacteria will aid in establishing the diagnosis. In aseptic necrosis of the femoral head, trauma with fracture of the neck or dislocation has usually preceded the condition, but in some instances such a history is lacking. Old congenital dislocations present the typical history of disability beginning the second year of life with or without subsequent treatment.

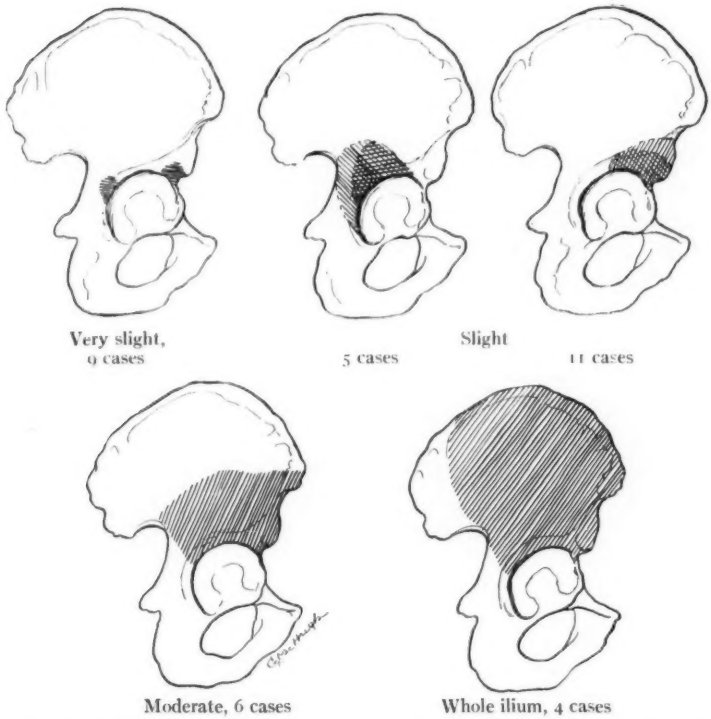

Fig. 9. Sketch representing relative anatomic location of focus of osteomyelitis in 35 representative cases in which the osseous focus in the ilium was responsible for suppurative coxitis.

Fig. 10. Case 9, B. C., aged 6 years at onset. Illustrative of a stable hip joint due to a fragment of the head or neck remaining. Roentgenogram taken 8 years later (age 14 years). This patient's chief disability was due to shortening on the involved side. Motion in the involved hip was normal except in adduction-abduction.

The appearance of the femoral head depends upon the age of the patient when treatment was first applied and the success thereof. The rarer conditions here enumerated are either characteristic in the roentgenogram or are definitely diagnosed as a result of biopsy.

TREATMENT OF ACUTE STAGE WITH END-RESULTS

After a review of these cases, one conclusion is apparent: the majority of complications resulting from this disease are avoidable provided an early diagnosis is made and prompt and efficient treatment is applied. An unsatisfactory result will be obtained only under exceptional circumstances: in the very young when extensive embolism of the upper femur has occurred and when there is bilateral hip joint involvement. Results in the latter case will be discussed in a special section.

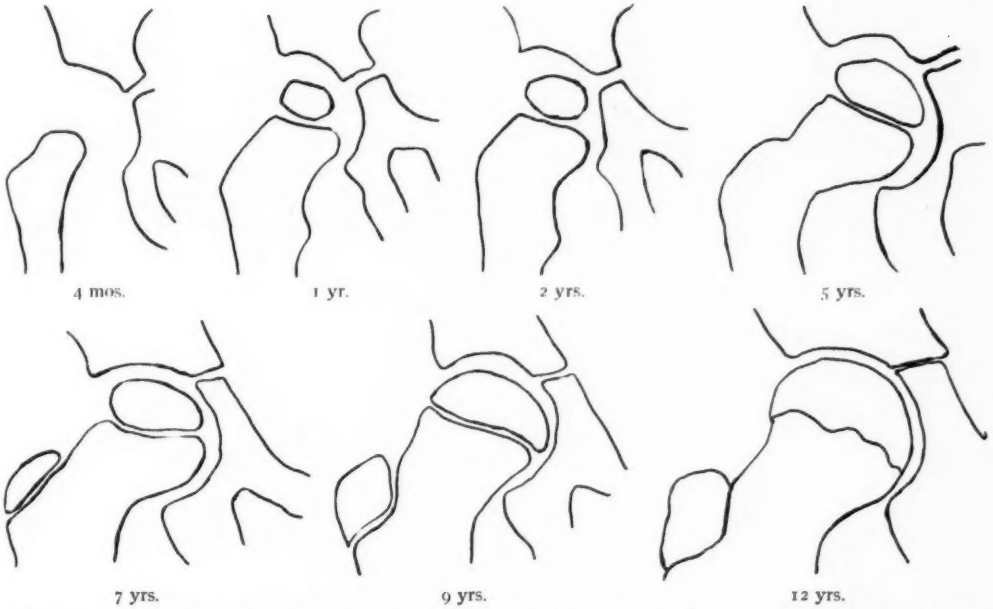

Fig. 12. Tracings of roentgenograms showing relative size of the osseous center for the capital femoral epiphysis at various ages: 4 months, 1 year, 2 years, 5 years, 7 years, 9 years, 12 years.

Early arthrotomy should be performed if symptoms have not subsided after aspiration of the hip. The routes of surgical approach to the hip have been standardized and will not be given here. Two methods have been used by the authors: the anterior approach described by Sprengel and the posterior route advocated by Ober. If treatment is subsequently carried out by means of a cast, either route can be selected, since the patient is easily turned, but if traction is to be used, the posterior approach is preferred. A soft rubber drain should be placed down to the margins or capsule of the joint but should not be allowed to press upon cartilage in the presence of the pyogenic exudate. Traction should be placed immediately upon the involved extremity and should be allowed to remain for a prolonged period. Treatment by a cast should be employed only when bone destruction is extensive and pathological fracture imminent. Since the extent of bone suppuration cannot be accurately evaluated for two or more weeks after the acute onset, efficient extension (preferably "balanced" Russel traction) should be employed as loss of bone by pathological fracture and pressure can be avoided. Figure 8 demonstrates roentgenograms of a patient in whom septic embolism of the upper half of the femoral neck occurred with death of the upper

Fig. 11. Case 10, R. P., aged 12 years at onset. Illustrating end-results from bilateral suppurative arthritis of the hips. Roentgenograms taken 4 years after onset show pathologic dislocation on right side and stable fused hip on the left side. The patient's gait was good, being far better than in the average case with unilateral involvement.

a b c

Fig. 13. Case 11. a, b, and c show the evolution of an osteomyelitic (hemolytic staphylococcus) infection of the upper femur with pyogenic hip joint involvement. The patient received adequate dosages of sulfathiazole orally for 2 weeks during the acute stage. Three aspirations of the hip joint yielded only a few (5 to 10 c.c.) of purulent fluid. These measures and Buck's extension by adhesive tape were only ones used. The clinical course and absence of cartilage destruction are typical of many juvenile patients treated by the sulfonamides. There is no positive proof that these drugs were solely responsible for observed benign course and outcome but it is suggestive they may have modified the course of the disease. a, Six weeks after onset of symptoms (a roentgenogram 2½ weeks after onset showed no osseous alterations); b, 3 months after onset; c, 14 months after onset. No incisions were made over femoral focus and no accumulation of suppurative products in soft tissues of thigh and no sinuses were observed. Full weight-bearing was allowed 4 months after onset; modified ambulation (crutches) after 1 month.

one-third of the femoral head. This result is attributable to continuous extension and early drainage. Figure 10 illustrates another case in which hip joint stability remained because a portion of the femoral neck was sufficient to articulate with an acetabulum. A tabular view of the type of treatment in our cases (arthrotomy or traction or both and other methods) is presented in Table VII.

The results in patients who were treated by us when they were in the acute stage have been satisfactory as compared with end-results in this whole series. A study of the number of stable hips, including both fused and mobile hips, is given in Table VIII. An "unstable" hip in this study is one in which bony ankylosis is not present and one in which superior displacement of the upper femur occurs when weight is borne on the extremity or reverse traction is applied. The possessor of a unilateral unstable hip can be easily identified by the classical "hip lurch." From this tabular summary and an analysis of individual cases, it is seen that almost every hip receiving adequate treatment remained stable (89.1 per cent of 46 hips). Of the 5 unstable hips occurring after adequate treatment had been followed, 2 were the contralateral hips in bilateral acute suppuration, while the 3 others were instances in which the entire neck was destroyed by septic embolism. Conversely, unstable hips often resulted when early drainage and traction were not employed.

Dislocation of the hip is preventable except in very young patients in whom the pyogenic exudate dissolves the entire upper femur, which is largely cartilage. This accounts for the ease of epiphysiolysis and subsequent pathological dislocation in the young. In preventing dislocation, traction with or without a plaster spica can be employed. Preservation of motion is favored by traction. The aim should be to combat by traction in abduction the "natural" and "comfortable" position of flexion and external rotation. When dislocation has occurred, the results in this series suggest that it should be reduced and held in traction unless the osteomyelitis is extensive when a cast will be preferred. Such reduc-

tions were performed and maintained in 10 hips. All those subsequently treated in casts ankylosed (7 cases) while those treated by traction (3 cases) remained in the acetabulum and now have more than two-thirds of a normal range of painless motion. Function in a hip, the site of pathologic dislocation, is not as good as when the hip is reduced, even though fibrous or osseous acetabular ankylosis develops. The end-results in the entire group relating dislocation to motion are given in Table IX. From a statistical point of view there is little difference whether the hip dislocated or remained in the acetabulum. In individual cases motion was best when joint cartilage remained and the hip was not dislocated. This latter tendency was favored when the infecting organism was the β-hemolytic streptococcus. At the same time dislocation was less frequent when this organism caused the infection, provided adequate bone was present about the hip, as in adolescents or adults. It is interesting to note that motion developed in 3 of 15 hips (20 per cent) in which the femoral head and neck were preserved and which were immobilized in plaster of Paris. In each of these 3 instances the time of immobilization exceeded 6 months. All now have stable painless hips and excellent (greater than two-thirds of normal) active motion.

The cases of bilateral suppurative arthritis of the hip present a special problem, particularly when dislocation of one or both hips has occurred. There were 2 cases in our 15 instances of bilateral suppuration in which treatment by traction was carried out after successful reduction of one hip. In both instances the contralateral side could not be reduced, since the entire head and a portion of the acetabulum had been destroyed by suppuration and pressure (Fig. 11). Ankylosis resulted in one reduced hip, while good function resulted in the other case. We would recommend reduction followed by effective traction when dislocation occurs here just as in unilateral involvement. Special care should be taken to prevent both hips from stiffening. However, functional results were found to be surprisingly good in our 9 cases of bilateral osseous ankylosis of the hips, all being able to walk rapidly by pivoting. The end-results from dislocation, necrosis, loss of the femoral head, and of other variants in this disease will be discussed under each age group. Roentgenograms of representative end-results in cases of bilateral involvement are given in Figure 12.

END-RESULTS IN SUPPURATIVE ARTHRITIS OF THE HIP, ANALYZED ACCORDING TO AGE OF ONSET

In this study it became clear that the reaction from infection in the hip in the very young (under 2 years of age) differs radically from that in older patients. This different clinical course would be expected because of the different reaction of cartilage and bone to infection. We have divided our cases for the purposes of analysis into 3 groups: 0 to 3 years of age, 4 to 12 years of age and into an older group of adolescents and adults. The basis for this division is the anatomy of the hip. Figure 12 illustrates tracing of roentgenograms of the hip region from representative children. At birth, the upper femur is composed entirely of cartilage, the epiphyseal center for the head not appearing in bone until the fifth to seventh month of life. The osseous center does not attain an appreciable size until 4 years, and the epiphyseal cartilage between the head and neck does not become very narrow until the age of 9 or 10 years. This accounts for the case of epiphysiolysis in the presence of suppuration before this latter age. In our experience the epiphyseal osseous center for the greater trochanter does not appear until the eighth or ninth year of age. All unite to the diaphysis at about the age of 17 years. End-artery zones are to be found along all bone articular cortical zones, including the entire circumference of the femoral neck and the entire surface of the pelvic bones that border on the acetabulum. Enchondral ossification and growth unrelated to an osseous epiphysis occur along all the surfaces mentioned, particularly at the femoral neck and adjacent to the y-cartilage. If the latter is closed by trauma or infection, deformity of the pelvis results. From the age of 10 to 12 years, the hip reacts to infection in about the same way as does an adult hip.

END-RESULTS OF SUPPURATIVE ARTHRITIS OF THE HIP IN PATIENTS UP TO THE AGE OF THREE YEARS

In this age group, particularly during the first year and a half of life, the symptoms are not clear-cut and the opportunity for the orthopedic surgeon to see the patient early and perform an accurate examination seldom occurs. The general physician and surgeon often does not realize that the abscess about the hip is the result of suppuration within a joint, the components of which are almost or entirely cartilaginous. If several days have elapsed before drainage is instituted, the cartilaginous head and neck have been destroyed by suppuration, and a pathological dislocation results even though traction is employed. Traction can be employed in the acute and recovery stages when the presence of a cartilaginous epiphyseal center for the head is not known but is suspected from the clinical examination. Eleven of the cases upon which we have end-result data fall into a restricted group in which suppuration occurred in the first few weeks of life, and 7 of these cases presented dislocation of the hip prior to reconstruction. The measure used in reconstruction of these hips will be discussed in a later section.

In such cases if pathological dislocation is present, the epiphyseal line has usually also been destroyed by suppuration. Since 12 per cent of the growth of the long bones of the lower extremity in a normal person comes from this epiphysis, appreciable shortening should theoretically be observed years later. Fourteen cases of this whole group (Table X) were seen again from 3½ to 14 years after the epiphyseal line was destroyed by suppuration. When loss of leg length due to bone loss and that due to dislocation were separately measured on roentgenograms, the total loss due to dislocation was practically identical with the difference in clinical leg length measurements in all save 2 cases. Since the epiphyseal line was destroyed in all these cases, compensatory overgrowth of other epiphyses in the other lower extremity must be postulated.

The end-results in terms of bone loss and stability correlated with the initial lesion are given in Table VI. The effects of the loss of femoral head and neck from suppuration and its effect upon dislocation are seen most often in the youngest age group. In this age group, as well as in the following older group (onset before 13 years), shortening observed years later is due to loss of bone and to dislocation rather than to significant lack of growth of the involved femur (Table X).

END-RESULTS OF SUPPURATIVE ARTHRITIS OF THE HIP IN PATIENTS FOUR TO TWELVE YEARS OF AGE

Reference to Figure 12 shows that during this age period the separate epiphyseal centers about the hip reach their maximum size before uniting with the diaphysis. Symptoms and signs during the period can usually be elicited with accuracy so that diagnosis is not difficult. Eleven of the 69 cases in this group were seen in the acute stage. The infection originated in bone in all the acute cases and in 39 of 45 hips of the entire group in which this factor could be determined. End-results are given in Tables VI, VIII and IX. It is noteworthy that half the whole series had an onset during childhood and, likewise, the greatest loss of bone occurred since the incidence of osteomyelitis is greater here, and most of the neglected cases, sent to us later for reconstructive procedures, fell into this group. Fusion to the pelvis occurred when bone was lost and dislocation was less frequent. There was a greater incidence of hips with restricted motion present in this group, due to this and other factors. Closure of the proximal femoral epiphysis and the y-cartilage at the hip occurred in about two-thirds of the cases, as judged from inspection of check-up roentgenograms from which these end-results were obtained.

As is the general trend in these cases, the infection occurred in the bone about the hip prior to joint involvement since in 39 of 45 cases the original point of infection could be accurately determined from inspection of serial roentgenograms. The origin of infection was about equally divided between the skin and the upper respiratory tract, in line with the incidence of ear and respiratory infections in children. Only two-fifths (10 of 26 cases), in which the infecting organism was known, were caused by the β-hemolytic streptococcus.

Arthrotomy for drainage was carried out early in most of the cases (45 of 68 cases), but the beneficial effects of such a procedure were nullified to some extent by the fact that traction had not been used in half these cases. These latter cases were, at the same time, the ones that presented the major reconstructive problems. In the 23 cases in which traction was not employed or was used late in the acute disease, there was the greatest incidence of ankylosis in malposition and loss of leg length due to bone loss and epiphysiolysis. This was particularly true in the younger patients of this group. In patients beyond 10 years of age there was very little bone loss even when traction was not employed unless the original embolism was massive. The case illustrated in Figure 10 in which the hip remained stable due to neck fragments that remained falls into this age group. Traction was the determining factor in these cases and in others in which such a result was obtained.

The median value for the amount of shortening in this age group was 3 centimeters. In only 10 per cent of the cases were we unable to account for all the shortening by dislocation, bone deformity about the hip, or actual bone loss—illustrating again the minor significance of destruction of the capital femoral epiphysis. Reconstructive measures to combat this shortening will be discussed later.

Spontaneous ankylosis of the involved hip was common in this group (21 of 78 hips). These were largely patients who had been treated in casts or allowed to remain in bed without support to the limb. Gait and function were good if position of the limb was satisfactory, but this result was achieved by osteotomy if malposition had resulted (see section on reconstruction). In 11 instances the head, usually *in toto*, was removed as a sequestrum. In 3 patients seen by us at a later date, drainage had continued for 2, 6, and 8 years, respectively. Drainage promptly ceased upon removal of the necrotic head.

END-RESULTS OF SUPPURATIVE ARTHRITIS OF THE HIP IN PATIENTS OVER THIRTEEN YEARS AT ONSET

Even in the younger patients of this age group, the epiphyseal centers about the hip have reached their maximum size, but those at the upper femur do not unite with the shaft until the age of 16 in girls and 18 or 20 in boys. Thirteen of the 43 cases in this group were seen in the acute stage. The infection originated in bone in 4 of 10 cases in which the initial focus could be determined in follow-up roentgenograms. The most diverse origin of the infection was encountered in this group: puerperal and other septicemias, gonococcus infection, infection following operative reduction of dislocation of this joint, as well as the usual infections that proceed from the skin and upper respiratory tract. The causative organism, when known, was usually found to be the Staphylococcus aureus (16 of 19 cases). Such a finding may be explained by either the large number (28 cases) for which this information was not available or the less incidence of upper respiratory infections in this older age group.

Arthrotomy was performed in only 7 of the 13 acute cases and traction employed with open drainage in only 4 cases. In these acute cases, spontaneous dislocation was encountered but once and this directly following removal of support (cast) in a relatively acute stage of the disease. In general, in this group, the extreme of bone involvement was less and loss of leg length due to either bone destruction or dislocation was minimal (median value being 0 cm.) when the whole group was viewed. However, such findings do not lessen the indications for traction as the amount of bone involvement is still a factor that cannot be evaluated until visualized by roentgenograms which always lag 7 to 14 days behind the actual changes. In 2 cases of the group, prompt and continuous application of traction undoubtedly prevented pathological fracture and subsequent shortening due to bone loss (Fig. 8), while in other cases traction indifferently applied resulted in fracture.

When this group of 47 hips is analyzed, dislocation was the end-result in 7 instances; all these remained mobile except one case. The most common outcome was that of preservation of motion in the primary acetabulum (32 of 47 hips). All of these, with but 2 exceptions, had greater than 50 per cent active motion at the involved hip. In this group of

adults, pain was a noticeable and prominent complaint in 10 of the 32 hips (see section on reconstruction). This is in contrast to the movable joints in the two younger groups of patients in whom a painless mobile and stable joint was a frequent outcome. It should be pointed out that these end-results from suppuration in children carry them only into the third decade of life. Undoubtedly, presenile osteoarthritis accompanied by pain will later result in a certain number. In defense of the mobile joint, it should be pointed out that they will have enjoyed 20 years of painless and unrestricted locomotion. Spontaneous fusion occurred in the primary acetabulum in 8 of the whole series. Prolonged cast immobilization was the determining factor in the last mentioned group, and indeed appeared to be the only factor in the entire group that favored the certain outcome of fusion. Motion developed in many patients after cast immobilization as well as after traction. Conversely, ankylosis did not occur in a single case when traction was employed.

Since bone loss due to suppuration was not commonly seen in this group, disability due to shortening was negligible, there being only one-third of the group presenting shortening as an end-result (17 of 47 hips). The median value for the entire group was 0 centimeter and for those showing shortening was 2 centimeters. The 5 cases in which gross bone loss occurred were all associated with massive or appreciable osteomyelitis of the upper femur (Table VI).

Due in some measures to the adult structure of the bone and the minimum amount of cartilage present within the joint, sequestration of the entire femoral head was not observed in this group, except in 4 instances in which it followed pathological fracture through the femoral neck in instances of massive osteomyelitis of this region. In 9 additional cases, the superior portion of the femoral head (usually the superior third) became detached as a joint sequestrum. In these cases, study of serial roentgenograms suggested that this outcome was the result of embolism of the corresponding portion of the underlying neck and in 2 instances was associated with the capsular tears of previous hip joint dislocation. Removal of this sequestrum resulted in prompt cessation of drainage except in cases of massive osteomyelitis.

CHEMOTHERAPEUSIS IN SUPPURATIVE HIP JOINT DISEASE: PREVENTION OF JOINT SUPPURATION

During the years required to compile the data for this report, to follow up the patients, and to analyze the end-results, the sulfonamide group of drugs came into clinical use. Their value has now been determined for almost every bacterial infection. While the end-results in this report are from cases in which the sulfonamide drugs were not used in the acute stage, experience with several acute cases in which patients were treated in the acute stage with the sulfonamides, chiefly sulfathiazole, demonstrates that these drugs do not alter the essential clinical course of joint suppuration. Their chief value appears to be in limiting suppuration. As a rule, fewer cases require arthrotomy and more can be carried over the acute stage by repeated joint aspiration. It also appears that fewer primary and secondary operations are required upon osseous foci of suppuration in patients who have received sulfonamides, particularly in children. The essential osseous picture following suppuration is not changed but modified in the direction of lessened virulence (Fig. 13).

The use of these drugs in the acute stage makes early bacteriologic diagnosis by blood cultures and by joint aspiration necessary in order to select the specific drug, although sulfathiazole and sulfadiazine appear to be sufficiently active against all pyogenic microorganisms. It has been demonstrated that the concentration of sulfathiazole is two-thirds to three-fourths of that present in the blood in joints the seat of effusion (and presumably also in joints the seat of suppuration). Since suppurative joint disease is often a complication of neighboring osteomyelitis, we can anticipate fewer instances of suppuration within the joints in the future, if vigorous chemotherapy is employed at the earliest moment. While the record is not yet clear as to the exact value of these drugs in limiting osseous suppuration, they have definite value in less-

ening the severity and duration of the blood stream infection and have a favorable effect upon temperature in septicemia and osteomyelitis. Surgical attack upon the bones at an appropriate time is still important, but with the use of the sulfonamides, greater conservatism in handling the osseous foci is possible. The surgeon can await the evidence of localization in roentgenograms with less danger of joint and other complications when these drugs are employed. While the results of bacterial culture of the blood and joint aspirations are awaited, chemotherapy can be tentatively started, sulfathiazole or sulfadiazine being used. Osseous and suppurative joint complications from the upper respiratory tract should receive sulfanilamide (hemolytic streptococcus) while those complicating skin infections should receive sulfathiazole (staphylococcus) pending receipt of data from the laboratory.

Evidence is accumulating that the metastatic effects of suppuration from upper respiratory origin (including middle ear disease) and from the primary sites of invasion of staphylococci are less in incidence and severity under the influence of chemotherapy. Many years of accurate clinical observation will be necessary to show the exact rôle these drugs have in the prevention of osseous and joint complications. The evidence to date indicates that the earliest possible bacteriologic diagnosis should be established both in the preceding conditions that give rise to bone and joint suppuration and in osseous complications themselves. The application of chemotherapy, though, should not minimize the surgical and mechanical principles stressed in the previous sections of this paper.

SUMMARY AND CONCLUSIONS

1. In a study of the end-results of suppuration in 147 hip joints in 132 patients of all ages, a relatively benign course of the infection is observed under the following conditions: (a) in the very young (beneath the age of 2 or 3 years) and in older persons (beyond the age of 15 or 16 years), in whom bone involvement is often restricted in extent; (b) in other age groups the bone lesion being small or non-existent; (c) in cases in which early arthrotomy and prolonged and continuous extension is employed.

2. The greatest disability and prolonged course of the disorder appeared in patients whose disease had followed massive osteomyelitis. Joint sequestra, ankylosis, and loss of bone from the femur are commonly seen under these circumstances.

3. The end-result of a movable hip stabilized in the primary acetabulum appears to be more desirable than an ankylosed hip unless such motion is accompanied by pain. In juveniles, such a movable hip may function for many years before pain disables the patient. Even when epiphysiolysis and loss of portions of the femoral head and neck occur, many cases come to this end-result if favored by continuous extension and prolonged recumbency. Serial roentgenograms are a necessity in applying treatment, especially after the bone lesion is visualized.

4. The variety of causative organism appears to effect the outcome only in so far as the hemolytic streptococcus is usually associated with minimal bone destruction and the hemolytic staphylococcus with moderate or extensive osteomyelitis.

5. The factor of sex has no influence on the outcome.

6. The segregation of cases of suppurative arthritis of the hip according to the age groups suggested (a) the very young (inclusive to 3 years); (b) children (4 to 12 years, inclusive); (c) adolescents and adults (more than 13 years of age); is warranted upon the basis of a different outcome in each group. This outcome is in turn also conditioned by natural factors which are uncontrollable, such as the severity and extent of infection, and by the type and duration of treatment applied.

7. Loss of leg length is chiefly due to dislocation of the hip and bone loss. The former is commonly seen and is the only factor producing shortening in the very young and in adults unless pathological fracture occurs in bones involved by extensive osteomyelitis.

8. The specific influence of the above factors is illustrated by the histories and roentgenograms of cases. The clinical course and deformities observed fall into definite groups determined largely by the amount and

location of the destruction and the treatment applied.

9. Early diagnosis by joint aspiration early in the course of the disease is possible when roentgenograms fail to show the presence and extent of bone changes.

10. Chemotherapy with either sulfathiazole, sulfanilamide, or sulfadiazine should begin immediately following early bacteriologic diagnosis, both in acute osseous bone and joint suppuration, and in the conditions which are known to serve as a primary focus for such infections. Presumptive chemotherapy may begin before laboratory data are available if the history is carefully analyzed. Penicillin, although promising, has yet to be applied to this group of cases.

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ORIGIN OF OVARIAN ADHESIONS FROM ORGANIZED LIQUOR FOLLICULI IN THE RHESUS MONKEY

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IN the course of numerous laparotomies performed on the rhesus monkey (Macaca mulatta) at the Carnegie Laboratory of Embryology in Baltimore, the writer every now and then observed (Hartman, 1937) an ovary that was connected with the omentum or with the tubal fimbriae by one or more strands of tissue, mostly thread-like but ranging up to 1 millimeter or more in diameter. A similar observation by the writer had been made many years previously in the opossum. Since on one occasion a very fresh and blood-red strand was seen to arise from the stigma of a recently ruptured follicle and peripherally was already attached to the fimbriae, it appeared entirely possible that such adhesions consisted of organized strands of drawn out liquor folliculi. Special attention, therefore, was given to this phenomenon and a collection of over two dozen cases has been analyzed. The series covers early stages in the genesis of the adhesions as well as their persistence over a period of several months.

In order to understand how the liquor folliculi issuing from an open rupture point in the early development of the corpus luteum can form a scaffolding on which connective tissue and blood vessels may grow to form a more or less permanent structure one must be familiar with some of the characteristics of the liquor folliculi of the freshly discharged follicle.

CHARACTERISTICS OF THE LIQUOR FOLLICULI

A. Robinson (1918) was the first to describe the succession of three phases in the secretion of fluid secreted into the cavity of the graafian follicle. His description has since been corroborated and the phases have been more accurately fitted into those events of the sexual cycle grouped around the process of ovulation.

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Liquor folliculi of the first order is secreted during the phase of slow growth of the follicle. It is dense and somewhat viscous and comes to surround the ovum and its corona radiata. During the preovulatory spurt of growth of the graafian follicle there is secreted a much thinner fluid relatively free of coagulable material, which is deposited at the free surface of the granulosa membrane. It is this liquor folliculi of the second order to which the rapid preovulatory growth of the follicle is due. This fluid is the portion that issues with a spurt at ovulation or when the ripe follicle is pricked. Its function is to free the viscid mass containing the ovum at the center. It is the writer's idea that the liquor folliculi of the first order plays an important rôle in the extrusion of the ovum. It functions presumably in forming a pliable mass on which the powerful cilia of the enveloping fimbriae can get hold and thus drag the imprisoned ovum out, as witnessed for example by the lines of tension in a section of a freshly ruptured follicle (Fig. 12 in Hartman, 1939).

After the collapse of the follicle and even while its wall is metamorphosing into the corpus luteum, secretion continues and liquor folliculi of the third order is produced. In the writer's view this is the material which forms the skeleton on which the adhesions about to be described develop. It is exceedingly viscous and in the fresh state very tenacious, so that by touching a cotton swab to the stigma of a fresh corpus luteum the material may, in a favorable case, be made to adhere and may then be pulled out into a strand 1 or 2 inches long, and this may be repeated several times on the same specimen, though the succeeding strands are progressively shorter. Very often this gelatinous liquor folliculi of the third order may be seen forming the center of the plug closing the stigma, the granulosa or lutein tissue forming a rim around it. The swelling of the corpus luteum is due partly to

the accumulation of the liquor folliculi of the third order in the lumen of the gland.

Such tough liquor folliculi may arise in spontaneously formed atretic follicles in both the monkey and the opossum. It is especially marked in atretic follicles produced by overstimulation by gonadotropes (Hartman, 1938, 1943) when the antrum becomes filled with coagulable material so firm that after fixation the contents of the follicle may be lifted out in a solid mass.

EARLY STAGE OF THE ADHESIONS

The records contain 4 cases in which adhesions were observed "in the making"—strands of blood-red, hyaline substance still imperfectly organized and vascularized, extending out from the ovarian stigma.

Monkey No. 645 ovulated between day 8 and day 9 of the December, 1938, cycle; ovulation was checked by laparotomy on the following day. Expecting an early ovulation also in the January, 1939, cycle, the female was mated on day 8 and laparotomized on day 15. The prediction proved wrong, for ovulation had just taken place, a well preserved unfertilized egg being recovered (C 634). The stigma consisted of a crown of red-orange granulosa tissue surrounding a hyaline strand continuous with similar material within the freshly ruptured follicle. Nothing is stated in notes as to distal attachment of strand.

Monkey No. 466 also furnished an unfertilized ovum (C 583). From the blood-red stigma measuring 2 by 3 millimeters (Figs. 1 and 2) the granulosa herniated out in a strand about 4 millimeters long and 0.5 millimeter in diameter and from the tip of this a finer thread proceeded to the edge of the fimbriae. The basal portion contained granulosa cells. This specimen we regard as the very beginning of the new type of adhesion here described. It might be designated as "Exhibit A" in evidence favoring the theory here advocated.

Monkey No. 395 received a course of treatment with gonadogen (pregnant mare's serum extract, Upjohn) from February 11, 1937 (day 7 of the cycle) to February 17. On February 19 the ovary was removed. From fresh corpus luteum, estimated to be 1 day old, a delicate adhesion extended to fimbria.

In Monkey No. 462 ovulation was diagnosed by palpation on October 12, 1937, day 9 (or 10?) of the cycle. At laparotomy 2 days later 2 adhesions were seen on the right (active) ovary, one very delicate thread running out from the small new stigma, the other stouter one, 1 millimeter in thickness, from a papilla marking the site of a corpus albicans. On October 22 an 11 day embryo was removed together with the ovary. Only one adhesion remained, the older and established one, the other having been resorbed.

CONTINUITY OF ADHESIONS WITH CORPORA ALBICANTIA

The continuity of the strands with the first corpus luteum in the 4 cases just described seems clear enough; but if the theory here proposed is to be proved correct it is necessary to demonstrate continuity of old, well organized adhesions with corpora albicantia. This has been done. Besides, in a number of cases, luteal cells identical with those in the corpus albicans have been traced into the basal portion of the adhering tissue.

It should be stated, however, at the outset that in 4 instances in which this point was investigated the adhesions are traceable back merely to the generalized ovarian stroma. This is not surprising, inasmuch as Corner (1942) has shown that within about 6 months the monkey corpus luteum disappears without leaving a trace. Thus, for example, in Monkey No. 334 the last ovulation had occurred 84 days prior to the removal of the ovary with its adhesion to the omentum. This period thus represents the minimum age of this adhesion. In the opossum, in which I have observed similar adhesions, the corpus luteum remains recognizable for only 3 months (Martinez-Esteve, 1942).

Parenthetically, it might be pointed out that in the 10 cases in which the adhesions are traceable to recognizable remains of corpora lutea these are never of the peculiar type discovered by Corner (3), and called corpora aberrantia by him, but are always the corpora albicantia as we know them from human ovaries. A few examples may be given.

Monkey No. 324 furnished the most bizarre ovaries yet encountered (Figs. 3 and 4). One would be inclined to reject this case as one not pertinent to the issue were it not for the fact that at least 2 of the many adhering strands are directly traceable to corpora albicantia (Fig. 5), that remains of luteal cells are to be seen in them, and that before the ovaries were removed the corpora lutea twice were seen to herniate excessively. The following protocol is necessary for a proper evaluation of the case.

The animal was received on November 20, 1934. Showed fairly normal menstrual cycles from the time of her arrival, with probable ovulations. Ovulation was diagnosed March 20, 1935 (day 12). Three days later a fragmenting ovum (C 534) was washed out of uterus via the cervix, by means of a hypodermic syringe, the needle of which was thrust through the abdominal and uterine walls. This was repeated on

April 25, without, however, this time recovering an ovum. On December 31 the uterus was flushed during laparotomy, that is, with the abdomen open, and left ovary was removed because of numerous adhesions.

The current corpus luteum had herniated out and spread toward the hilum. On December 14, 1935, the uterus was again flushed through and 2 days later an exploratory laparotomy was done. On this occasion the 3 needle holes in the uterus were still visible and from 2 of them delicate adhesions emanated. The ovary showed nothing unusual, being entirely free of adhesions. On January 18, 1936, a defective 11 day embryo was removed by hysterotomy. The accompanying ovary showed again a very large, much herniated corpus luteum. This surviving ovary was finally removed on March 17 and for the third time in this animal a herniated corpus luteum was found, this time markedly everted, at least nine-tenths of the volume being "outside" the ovary proper (Corner, 1943).

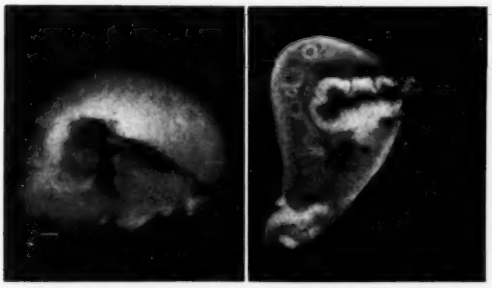
To summarize this case, we find associated with a marked tendency of the corpus luteum to herniation (as seen in 3 laparotomies) the most excessively developed system of adhesions, several of which are traceable to corpora albicantia. The adhesions are hardly referable to trauma incident to prior puncture of the uterus with a hypodermic, for this was confined strictly to the uterus and the surviving ovary, removed later, had no adhesions.

Several other cases out of the 11 in which the continuity of the adhesion with luteal tissue was established, may now be described.

No. 460, not previously operated upon, was laparotomized for the purpose of removing a 23 day embryo (C 597). A fine thread of tissue was seen attached to the current corpus luteum.

No. 611 furnished the ovary shown in Figure 7 on February 3, 1941. The tag of tissue protruding from the ovary was connected with an old corpus albicans. The ovary contained the current corpus luteum (of which the pale stigma is seen to the left of the process in the illustration), a corpus albicans of the previous cycle and the one in contact with the adhesion (Fig. 8). The finely vacuolated luteal cells are spread out to the base of the adhesion but do not enter it. On the preceding October 20 a 12 day embryo (C 654) had been removed by hysterotomy. At this time there was no adhesion to either ovary; the stigma was also pale and anemic as on the later occasion. Whereas No. 324, already discussed, showed a tendency to herniation of the luteal tissue, No. 611 had nonprotruding pale stigmas (2 observations); nevertheless this animal also developed an adhesion.

No. 660. In the case of this monkey the graafian follicle broke under the palpating finger on October 23, 1939 (day 11) and a laparotomy was performed 6 days later. A corpus luteum had formed; there was no adhesion. On December 20 the animal was hysterectomized and the remaining ovary removed (11 day ovum No. C 662 was recovered). Figure 9 shows the fresh cut surface of the ovary, with current corpus luteum (pale) and that of the preceding cycle (dark), from which stems an adhesion. This contained luteal cells comparable with those of the adjoining corpus albicans (Figs. 10 to 12).

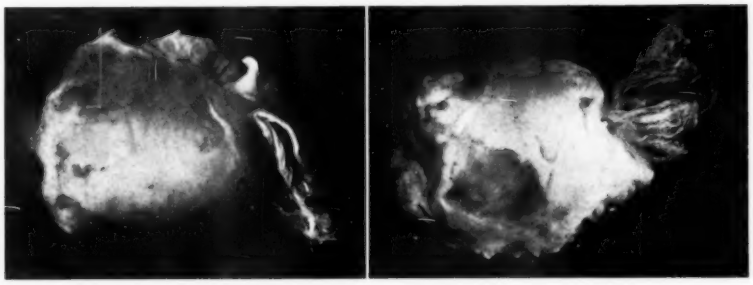


Figs. 1 and 2. Surface view and cut surface of ovary halved, showing adhesion continuous with the lumen of the corpus luteum. Monkey No. 466. Photographed fresh. ×3.2.

SIZE, NUMBER, AND PERSISTENCE OF THE ADHESIONS

As already appears from the data thus far presented the ovarian adhesions range in size from delicate threads to strong bands several millimeters in diameter. Eight entries in the records give about 1 millimeter as the thickness, and 8 others are designated in the notes as fine or delicate; a half dozen were described as thick or coarse and of these No. 324 represents the extreme both as to number and as to coarseness. Eight cases had 2 adhesions each, mostly of different thickness, and in all but 1 they arose from different points on the ovarian surface. In several cases it could be shown that the members of the pair arose from corpora albicantia of different ages. No. 677, however, was unique: 2 strands arose from the same point on ovary and inserted at separate points on omentum. Here the point of origin could not be related to a corpus albicans.

That the adhesions persist for months is clear from successive direct observations as well as other evidence, as for example the age of the corpus albicans (Corner, 1942). On the other hand, in 2 cases the strands were ephemeral. That of Monkey No. 462 was a delicate



Figs. 3 and 4. Two surfaces of ovary of Monkey No. 234 showing two masses of adhesions. Photographed fresh. ×3.2. (Section shown in Fig. 5.)

thread running from the stigma of a fresh corpus luteum seen at laparotomy on October 14, 1937. This was no longer present 8 days later, whereas another older strand 1 millimeter in thickness had persisted. Observations on the second case, No. 659, are especially suggestive. On October 25, 1939, a laparotomy was performed to check a diagnosis of ovulation and on this occasion an adhesion was seen and a sketch of it made. Ten days later only the stump of the adhesion remained in the form of a coarse papilla (Fig. 13). Since papillae are sometimes seen on ovaries (as for example that shown in Fig. 14), the case just cited might offer the explanation as to the genesis of some of them and also suggest that established adhesions may also break and be largely resorbed.

Exact ages of a number of adhesions are known because the ages of the corpora lutea to which they are attached are known. Those found in Nos. 282, 611, and 660 were 11 or 12 days old; that of No. 460, still a fine thread, 23 days; that of No. 680, 60 days. No. 401 had no adhesion on October 27, 1936, but on November 24 there was an adhesion 10 days old. In the case of No. 457 a delicate thread was seen between ovary and fimbria and sketched on February 7, 1937; it was still there on March 29. The fresh adhesion in No. 677, December 7, 1939, was removed with ovary 2 months later. The very delicate thread

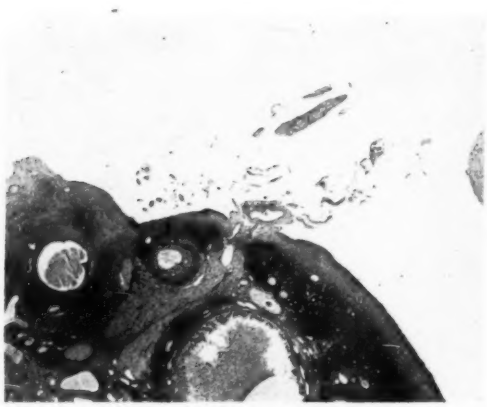


Fig. 5. Section of the ovary of Monkey No. 234 shown in surface view in Figures 3 and 4. The continuity of the adhesions with a corpus albicans is seen. ×13.

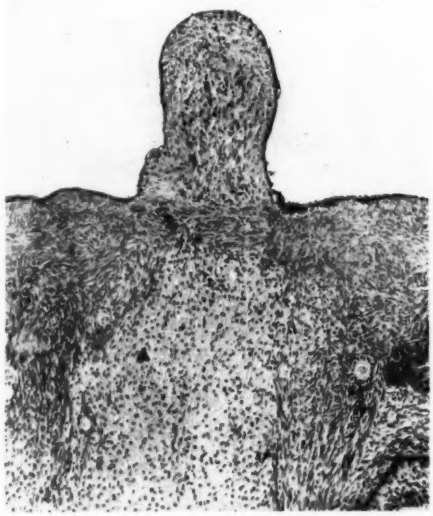


Fig. 6. The similarity of the tissues of the corpus albicans and the papilla constituting the base of an adhesion is apparent. Section of ovary of Monkey No. 282. ×70.

Fig. 7.

Fig. 9.

Fig. 7. Surface view of ovary of Monkey No. 611 to show adhesion. Photographed fresh. ×3.2.

Fig. 8. Section of ovary shown in Figure 7. The adhesion emanates from a corpus albicans. ×9.

Fig. 9. Cut surface of ovary (halved) of Monkey No. 660. Current corpus luteum and that of the preceding cycle, with adhesion, are shown.

recorded on December 4, 1939, in No. 703 was still present February 12, 70 days later.

In 3 cases both ovaries were involved.

As to the incidence of the ovarian adhesions the writer can give only a rough estimate of perhaps 3 per cent. More careful examinations might have resulted in discovery of more cases.

PLACE OF INSERTION

In only half of the cases do the records indicate whether the insertion was on the fimbriae or on the omentum and these are

Fig. 8.

Fig. 10.

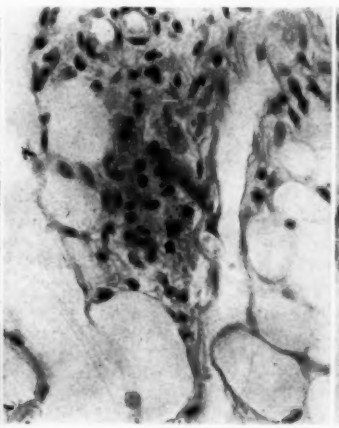


Fig. 11.

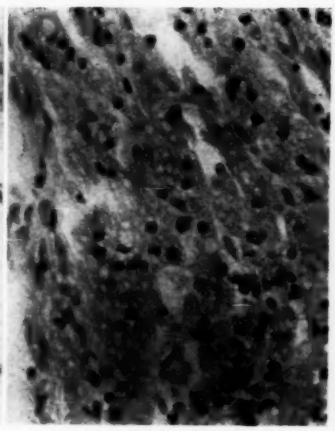
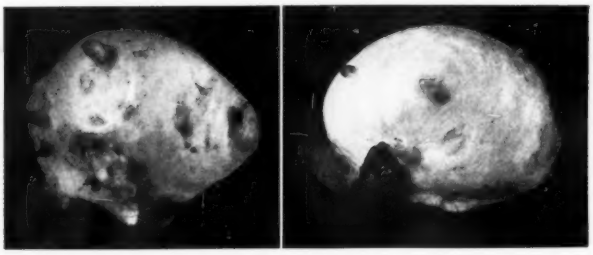


Fig. 12.

Fig. 10. Section of ovary shown in Figure 9, through adhesion and corpus albicans. ×34.

Figs. 11 and 12. Sections of portions of Figure 10; Figure 11 from the adhesion (upper ring in Fig. 10); Figure 12 from the corpus albicans (lower ring of Fig. 10). ×340.



Figs. 13 and 14. Ovaries of Monkeys Nos. 592 and 659 to show papillae that mark the remains (basal portions) of adhesions that all but disappeared spontaneously.

evenly divided, namely, 6 on each. As the fimbriae closely envelop the ovary at ovulation time and relax and withdraw from the ovary later, it follows that the attachments to the fimbriae probably occurred early in the life of the corpus luteum, as compared with the attachments to the omentum.

RELATION OF ADHESIONS TO PRIOR OPERATIONS

The question has already been raised (in connection with No. 324) as to whether the adhesions described are the result of trauma at prior abdominal operations; for, after hysterotomies, adhesions are, of course, common. A survey of the series, however, shows that in nearly half of the animals the adhesions were discovered at the first laparotomy. Generalized spontaneous adhesions of abdominal organs are rare in the rhesus monkey; 2 records only are available in our protocols so far as these have been searched.

SUMMARY AND CONCLUSIONS

It is concluded that in the rhesus monkey certain strands of tissue here described as running from the ovary to the tubal fimbriae or to the omentum arise by ingrowth of connective tissue and blood vessels into a scaffolding of viscous and tenacious liquor folliculi issuing as a thread from a fresh corpus luteum. Such strands have been seen in the making and their persistence has been followed by subsequent laparotomies. Older adhesions are often traceable to corpora albicantia, and luteal tissue may be found in the proximal ends of the strands. Even delicate threads have been shown to persist as long as 70 days; more robust ones probably last very much longer. In 2 cases, the adhesions proved to be evanescent structures, disappearing spontaneously. Certain papillae on the surface of the ovary may be remnants of such adhesions, as was proved in 1 case.

Whether such adhesions occur in women also the writer does not know. Perhaps such are brushed off by the surgeon as insignificant. It is conceivable that if they do occur in women as in the monkey female they at times cause a slight discomfort. Dr. G. W. Corner (personal communication) saw in a monkey an adhesion strong enough to have held an entangled loop of the intestine and possibly caused strangulation.

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SURGICAL APPROACH FOR TUMORS OF THE THYMUS

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THERE probably is no organ in the human body about which physicians have as little definite knowledge as they have about the thymus. The following quotation is from an editorial (5) which appeared in the *Lancet*. "The thymus gland . . . has remained an enigma. Endocrinologists have wooed it in vain. Physiologists and pathologists have drawn away from it baffled. Not even the anatomists or histologists have spoken of it with their customary precision for we are still uncertain whether it has any real existence in the normal adult and whether the main cells of its medulla are to be regarded as epithelial or endothelial." In recent years, however, there has been a considerable interest in this organ and, although it must be admitted that there is very little definite scientific knowledge about the thymus, there has accumulated a considerable body of evidence suggesting a relationship between abnormalities of this gland and the disease, myasthenia gravis. This association was first noted by Weigert, in 1901. Since that time, Bell, Norris, Blalock (3) and his associates (4), and others have contributed considerable evidence to support the thesis that abnormalities of the thymus manifest by enlargement or tumors of this organ occur in a much higher percentage of cases of myasthenia gravis than can be accounted for by coincidence. Further evidence of the association of myasthenia gravis and the thymus is that in selected cases deep roentgen therapy applied over the thymus has produced a remission of symptoms. In recent literature there have been reports of cases of myasthenia gravis in which this treatment has produced improvement and in some instances complete remission of symptoms has occurred.

The purpose of this paper is to consider the three main surgical approaches to lesions of the thymus gland, all of which have been employed by one of us (O. T. C.). The clinical results in 10 cases in which thymectomy was performed will not be considered at this time except to say that there has been but 1 death and the results have been satisfactory; in fact, sufficiently so to warrant further employment of thymectomy in cases of myasthenia gravis and, at times, even in cases in which there is no demonstrable thymic enlargement evident on x-ray examination of the thorax.

From the Division of Surgery, Mayo Clinic, and Mayo Foundation.

EMBRYOLOGIC AND ANATOMIC CONSIDERATION

The thymus gland (2) takes its origin from the 3d visceral cleft of each side and consists of two lobes, one of which is formed from each lateral diverticulum. The upper part is at first tubular but gradually becomes a solid structure. The thymus is believed by many investigators to be originally epithelial in structure, reaching its maximum growth and finally becoming mainly lymphoid in type by the end of the second year. The gland remains essentially stationary in growth until puberty, after which it rapidly atrophies.

The two lobes of the thymus lie in the midline in close contact with each other and extend from the lower border of the thyroid gland to the 4th costal cartilage. In the neck, the thymus rests on the trachea and is covered by the sternohyoid and sternothyroid muscles. In the thorax, the gland lies directly beneath the sternum; it rests below upon the pericardium, being separated from the aortic arch and large vessels by a thin layer of fascia.

The blood supply of the thymus is derived from branches of the internal mammary and superior and inferior thyroid arteries. The blood returns by way of the innominate, internal mammary, and the thyroid veins. The nerve supply to the gland substance is derived from sympathetic fibers and branches of the vagus. The thymic capsule is further supplied by branches of the phrenic and descendens hypoglossi nerves.

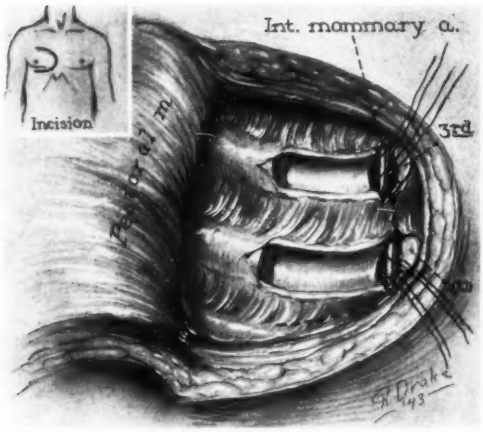

Fig. 1. Transcostal approach. Inset shows line of incision. The pectoralis major muscle is turned back, thus exposing the costal cartilages and internal mammary vessels.

Fig. 2. Transcostal approach. The pleura is retracted laterally and the thymic tumor protrudes from beneath the sternum.

SURGICAL APPROACHES

Three different surgical approaches for tumors of the thymus gland have been used, depending on the size and situation of the tumor and also on whether extensive irradiation has been used previously and has resulted in greater fixation of the lesion. Any one of these approaches will permit adequate exposure of the thymus, which we do not believe to be the case in all instances when the tumor is approached through an incision in the neck. The anterior transcostal and the sternum-

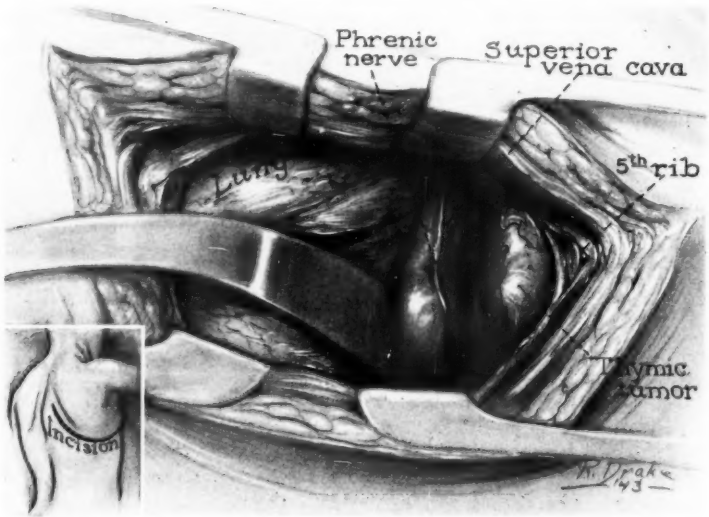

Fig. 3. Posterolateral approach. Inset shows the line of incision. A long segment of the 5th rib has been removed. The lung is packed off to one side, thus exposing the thymic tumor in the anterior mediastinum.

splitting approaches are entirely extrapleural, whereas the posterolateral approach involves opening the pleural cavity. The advantages, disadvantages, and technique of each approach will be considered.

Transcostal approach. This approach has the advantage of being not only an easy one to make but also one through which the operation may be performed extrapleurally; however, the exposure is not too satisfactory. This approach should be used only when the tumor is known to be a relatively small one and when there has been no extensive use of irradiation therapy.

The patient is placed on his back and a curved incision is made through the skin and subcutaneous tissue on the anterior thoracic wall. The pectoralis major muscle is turned back, which exposes the 3d and 4th costal cartilages (Figs. 1 and 2). The internal mammary vessels are isolated just lateral to the sternum and are doubly ligated. Two to 3 inches (5 to 7.6 cm.) of the 3d and 4th costal cartilages then are resected. The intercostal vessels are ligated and the posterior perichondrium is incised in a vertical direction just lateral to the course of the internal mammary vessels. By means of blunt dissection with the index finger, the pleural margin is located and retracted laterally. The thymus is then readily freed from the loose surrounding areolar tissue, and the thin extrapleural fascia, and is removed from the thorax. In some instances the thymus is quite firmly fixed to surrounding structures, thus necessitating the use of sharp dissection and accurate control of all bleeding points. Three to 5 grams of some chemotherapeutic agent then may be inserted and the operative site is drained with a Penrose drain. The vertical margins of the incised posterior perichondrium are approximated with interrupted sutures. The pectoralis major muscle is allowed to fall back into its normal position and the subcutaneous tissues are closed with interrupted sutures of plain catgut. The skin is closed with either interrupted sutures or a running locking dermal suture.

Posterolateral approach. This approach permits the most adequate exposure for very large thymic tumors or for those which are

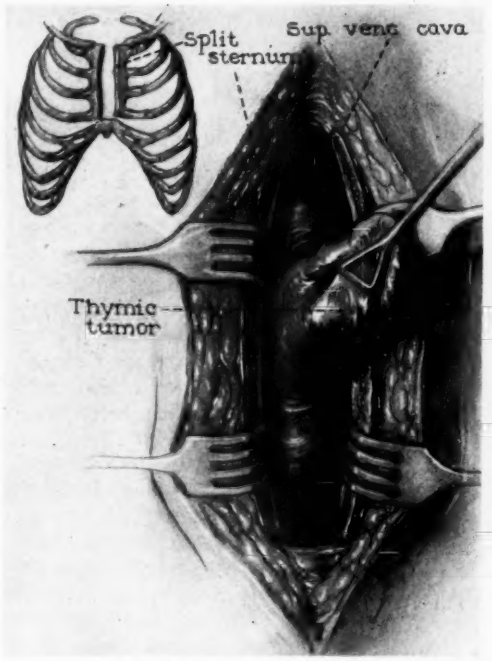

Fig. 4. Sternum-splitting approach. Inset shows the extent of the opening in the sternum. The sternum has been split and its edges have been retracted. The thymic tumor can be exposed readily directly beneath the sternum.

fixed to the surrounding vessels. With this approach, however, it is necessary to open the pleural cavity and, although the danger is slight, one must accept the complications which do occur occasionally when the pleural cavity is opened, such as atelectasis resulting from unsatisfactory re-expansion of the lung, or empyema resulting from infection. A technical disadvantage to this approach is that the surgeon is working at the end of instruments, which is not the case when the anterior approach is used.

The patient is placed on either side, depending on the situation of the tumor, and is strapped firmly into position. A curved posterolateral incision is made on the right side. The incision is begun midway between the edge of the scapula and the vertebrae and extended laterally beneath the scapula (Fig. 3). The trapezius and rhomboid muscles are incised superiorly, while the latissimus dorsi and portions of the anterior serratus muscles

Fig. 5. The Lebsche sternum splitter.

are incised inferiorly. The scapula then is elevated and the 5th rib is localized. With the use of the Alexander periosteal elevator, the periosteum is carefully freed from the rib and a long segment of the rib is resected. All bleeding usually stops when the rib is removed but, on occasions, the intercostal vessels and nerves must be ligated. The posterior periosteum of the rib bed and the parietal pleura then are incised, which allows one to open the pleural cavity directly. The lung becomes deflated and may be packed aside with a moist gauze pack which permits excellent exposure of the mediastinum and its structures. The mediastinal pleura then is incised over the tumor and the thymus is removed by either blunt or sharp dissection, depending on the amount of fixation present. After the tumor has been removed and hemostasis is accomplished, the operative site is washed with physiologic salt solution and 5 grams of sulfanilamide, or an equivalent amount of sulfanilamide, is sprinkled into the thorax. The opening in the mediastinal pleura then may be closed. Usually, a rubber catheter is inserted through a stab wound made one intercostal space below the incision, in the posterior axillary line. The anesthetist then employs a positive pressure of 10 to 12 millimeters of mercury, which is sufficient to re-expand the lung. While the thorax is being closed, constant suction through a rubber catheter is employed. This suction, plus the positive pressure anesthesia, aids in maintaining satisfactory re-expansion of the lung during closure. As an assistant approximates the edges of the wound, the wound is closed with a continuous running suture of chromic catgut in the parietal pleura and periosteum of the rib bed. The muscles are approximated with interrupted sutures. A few interrupted sutures are placed in the subcutaneous tissues and the skin is closed with a continuous locking dermal stitch. Water seal suction is applied to the catheter for 24 to 48 hours, at the end of which time the catheter is removed if roentgenographic examination of the thorax reveals that the lung is well expanded. Care must be taken at the time of removal of the intercostal tube to avoid having any air enter the thoracic cavity.

Sternal splitting approach. This approach permits the most direct access to the thymus and is the one favored in most instances. Owing to the situation of the thymus immediately beneath the sternum, its separation from the superior vena cava, the arch of the aorta, and the pericardium may be carried out most readily by such a direct approach. The operation is carried out entirely extrapleurally —another favorable factor. The only disadvantage is that one still does not have the surgical exposure which can be obtained with the posterolateral approach.

With the patient lying on his back, a midline incision is made, beginning 1 inch (2.5 cm.) above the manubrium and extending to the 4th costal cartilage anteriorly (Fig. 4). The soft tissues at the base of the neck are freed from the manubrium and the sternum is exposed in the midline throughout the length of the incision. The Lebsche sternum splitter, a fairly heavy instrument with a sharply curved surface at one end (Fig. 5) then is hooked under the manubrium and, with the use of an orthopedic mallet, the sternum is split to within about 2 inches (5 cm.) of the xiphisternal junction. At this point, transverse incisions are made through the sternum to allow wider retraction of the sternum. With sharp retractors, the sternal margins are retracted and exploration of the anterior mediastinum is then possible. The thymus is found lying directly beneath the sternum and is removed as in the previous instances, by blunt dissection when possible, or by sharp dissection when necessary. After all bleeding points have been ligated, 5 grams of sulfanilamide is placed in the wound and one Penrose drain is inserted. The sternal margins are approximated with steel wire sutures

which encircle the sternum at the level of the 2d and 3d interspaces. The anterior fascia is closed with interrupted sutures of chromic catgut and the skin is closed with interrupted dermal sutures.

ANESTHESIA AND POSTOPERATIVE TREATMENT

Cyclopropane and oxygen administered through an intratracheal tube are the anesthetic agents of choice in all instances. When the posterolateral approach is employed, the use of an intratracheal tube is imperative and even when either of the anterior approaches is used, the intratracheal tube should be employed as a safeguard, since the pleura might be opened occasionally.

The postoperative care is essentially the same in all instances. The patient is kept in an oxygen tent the first 2 to 3 days after operation. Roentgenograms of the thorax are obtained quite frequently. Since thymectomy is done mainly for myasthenia gravis, correct doses of prostigmine and ephedrine must be administered, depending on the severity of the disease. One should guard closely against any myasthenic reactions and it is best to have a Drinker respirator available in case severe respiratory depression should develop. The maintenance of satisfactory fluid balance, sedation, and other routine postoperative measures should be employed.

COMMENT

Since patients with myasthenia gravis have shown definite improvement and, in some instances, complete remission of symptoms following thymectomy, we believe that surgical exploration of the thymus should be carried out in all instances in which there is definite evidence of thymic enlargement. Whether this view will be broadened to include all cases of myasthenia gravis, regardless of positive evidence of the presence of a thymic tumor, depends on the results of this procedure as determined by observation for several years. The operation itself is not a difficult one and is made much easier when the correct surgical approach is employed. We would reserve the anterior transcostal approach for small tumors of the thymus which are situated high and anteriorly in the mediastinum. If extensive irradiation therapy has been administered before operation, this would be considered a contraindication for this approach. The posterolateral approach should be used in those instances in which maximal surgical exposure is required, as in cases of very large tumors or of tumors which have been exposed to extensive irradiation. The sternum-splitting approach is definitely the most satisfactory one and permits direct access to the thymus which is found lying directly beneath the sternum. If there is no fixation, blunt and sharp dissection of the tumor is a relatively simple matter, and if fixation is present, such a direct approach allows one more readily to dissect the lesion from the great vessels of the thorax.

SUMMARY

In some cases of myasthenia gravis, excision of the thymus is indicated. This organ may be approached transcostally by an extrapleural route, transcostally by a posterolateral-transpleural route, or extrapleurally by a sternum-splitting approach. Although the last approach perhaps offers the greatest advantages, selection of the approach should depend on the size and situation of the tumor as evaluated by clinical and roentgenographic studies of the thorax before operation.

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EXPLORATORY ANTERIOR MEDIASTINOTOMY IN THREE CASES OF MYASTHENIA GRAVIS

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THE purpose of this paper is to summarize and add 3 additional cases[1] to the growing literature on the value of surgical intervention in myasthenia gravis.

The relationship between myasthenia gravis and the thymus gland was first suggested by Weigert in 1901, who found a tumor of the thymus in a postmortem examination of a patient who had died with myasthenia gravis. Schumacker and Roth first reported the operative removal of a thymic tumor by Sauerbauch in 1912. Haberer reported a partial thymectomy on a patient in 1917. Two additional cases by Sauerbauch were reported by Adler and Obiditsch in 1937. Blalock (4) and the Vanderbilt group reported the first successful removal of a cystic thymic tumor in a case of myasthenia gravis with a 4 year follow-up showing definite improvement. In a survey of the literature Poer, using the figures of Bell, Norris, and Blalock, and collected data of personal cases, compiled a total of 129 instances of myasthenia gravis in which the thymus was examined at autopsy or operation. This study revealed thymic abnormalities in the form of persistence, enlargement, or tumor of the thymus in 71 instances, or 55 per cent of the total cases. Poer (Table I) also reported 1 case of the successful removal of a malignant tumor of the thymus in a patient with myasthenia gravis, with marked improvement in the patient's symptoms at the end of 3 months.

The first concerted effort to influence the course of myasthenia gravis by surgical intervention was carried out by Blalock, Harvey, Ford, and Lilienthal (5) at Johns Hopkins Hospital in 1941. Their report is based on 6 cases of myasthenia gravis in which an anterior exploratory mediastinotomy was done. In none of these cases was there roentgenographic evidence of a mediastinal tumor. There was a definite persistence of thymic tissue in all of the patients, but no tumors were found. Definite hyperplasia was demonstrated in all but 1 case. There was 1 death, marked improvement in 3 patients, and very little improvement in 2 patients at the time of publication of the study of these cases. In a subsequent communication from Dr. Blalock (3) he states: "During the past eighteen months we have removed the thymus from fifteen patients. None of these showed a tumor. Approximately half of the patients are markedly improved; some of the others have shown no improvement." Campbell *et al.* reported the removal of a thymic tumor in each of 2 cases of myasthenia gravis at a meeting of the New York State Medical Society in 1941. The first patient died suddenly on the 2d postoperative day, while the procedure on the second patient was moderately successful.

The Mayo Clinic reports (7) that in 9 of the last 55 cases of myasthenia gravis studied there was roentgenographic evidence of mediastinal tumors. In 5 of these cases surgical intervention confirmed the presence of tumor. A 6th patient was found to have a persistent thymus gland with tumor formation. Two of the patients who had thymic tumors were operated on during remissions, apparently induced by roentgen irradiation, and they have remained well. In 2 other cases the course of the disease was not influenced by removal of the tumor. One patient with tumor and 1 with a persistent thymus have been operated upon too recently to evaluate.

In the case reported by Turnbull in which a 7.5 by 4 by 2.5 centimeter tumor weighing 30 grams was removed, no improvement was noted at the end of 4 months. The tumor was described as a malignant thymoma of the lymphosarcoma type.

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[1]All patients were studied on the medical service prior to operation on the surgical service in the North Carolina Baptist Hospital.

REVIEW OF CASES

CASE 1. A.S.M., the patient, a 40 year old white farmer's wife, was first admitted to the hospital on September 2, 1943, with a history of progressive weakness of 12 years' duration. At the onset, she had noted a drooping of the left eyelid, which spread to involve the right eye. She had had mild diplopia on looking downward. Some 9 years prior to admission, weakness of the shoulders had become so severe that she was unable to hold the arms above the head. The condition had progressed until 4 years prior to admission she was having extreme difficulty in swallowing and talking; there was a constant drooling of saliva, due to inability to close the mouth. Two years prior to admission, the weakness had involved the hands; the first motion was performed rather easily, but repeated or sustained motion resulted in marked weakness and inco-ordination of motion. Fifteen months prior to admission the weakness extended to the lower extremities, associated with shortness of breath, and progressed to such an extent that the patient had to remain in bed. The diagnosis of myasthenia gravis was first made at the North Carolina Sanatorium for the Treatment of Tuberculosis, in August, 1940. She was a patient in that institution for 4½ months, where a diagnosis of moderately advanced apical tuberculosis was made, but the tubercle bacillus was never demonstrated in the sputum. She had no clinical evidence of active tuberculosis at that time; the diagnosis was based on x-ray findings.

She had been given prostigmin methylsulfate; 3 15-milligram tablets had been given daily; some improvement was noted over a period of 4 or 5 months. The dose was gradually increased to as high as 12 15-milligram tablets in a 24 hour period. The patient had often had to take the medication throughout the night because of respiratory difficulty. One year prior to admission, she was studied at another hospital, and the dosage of prostigmin temporarily decreased, with the addition of guanidine hydrochloride.

A review of the past history revealed pneumonia at the age of 15 years and repeated bouts of malaria at the age of 30, after the onset of the symptoms of myasthenia gravis. During the 3 years prior to admission, she had noted an irregularity of the menses, with intervals as long as 2 months, the periods lasting 4 to 7 days. Marked vasomotor instability had also been noted. There was no relief of myasthenic symptoms during pregnancies. She had lost approximately 25 pounds in weight during this period. There was no familial history of a similar muscular weakness, tuberculosis, or malignancy.

On physical examination the patient was found to be extremely weak; the weakness was much more pronounced on sustained or repeated muscular effort. She was unable to talk distinctly for any length of time, and in order to speak she had to manipulate the jaw with a supporting hand. She was unable to raise the unaided hand to the forehead because of weakness of the shoulders. Swallowing was accomplished with much difficulty. Respiration was shallow and rapid, and there was very little movement of the costal margin or anterior abdominal wall. The eyes were in fixed position, the lids half closed, and she was unable to open or close them. The head was carried in a semiflexed position, the neck being flaccid. There was some diminution in the weakness over the lower trunk and extremities. The head was symmetrical, without scarring or tenderness. Examination of the eyes revealed that the pupils were small, but reacted poorly to light; there was a failure of convergence. Examination of the ears revealed the canals and drums to be clear. The fundi had normal cupping of the discs and normal vascular pattern. The tongue protruded slightly to the right; there was a complete edentia. The deep tendon reflexes were intact and equal throughout. The plantar response was flexor. There was no myoclonia, and no fibrillary muscular twitchings were observed.

The accessory clinical findings were as follows: The urine was entirely normal. The hemoglobin was 12 grams. She had a red blood count of 4,500,000, and a white blood count of 5,200, with an entirely normal differential count. The nonprotein nitrogen was 32 milligrams per cent. The blood calcium was 10.8 milligrams per cent, the phosphorus 4.4 milligrams per cent. The corrected sedimentation rate was 10 millimeters. The blood Kahn was negative. The glucose tolerance test revealed a fasting blood sugar of 89 milligrams per cent, with a level of 125 milligrams per cent after 30 minutes, 147 milligrams per cent at 1 hour, 156 milligrams per cent at 1½ hours, and 105 milligrams per cent at 2 hours. The tuberculin test, using a dilution of 1:10,000, was negative at 24 and 48 hour intervals. Repeated sputum examinations, as well as examination of stomach washings, revealed no acid fast organisms. The skull films were negative, and a chest film revealed a clouding at the right apex, with small, discrete infiltrations radiating from the left hilum into the infraclavicular region of the left upper lobe, with stringy, fibrous strands in this region. No mediastinal tumor could be seen. The plate was interpreted as showing a left upper lobe tuberculosis, with questionable activity. Repeated chest films on this admission revealed no change in these findings. The chest films were repeated after the injection of 250 cubic centimeters of air into the anterior mediastinum, but no tumor or abnormality could be demonstrated.

Intra-arterial injection of 0.2 milligram of prostigmin, with a blood pressure cuff in place, gave marked local improvement in muscular strength; the remaining parts of the body remained weak. There was no fasciculation noted in the injected arm. No abdominal cramps were noted upon release of the pressure in the sphygmomanometer cuff.

During her 22 day stay in the hospital, she was given combinations of glycine, ephedrine, and oral prostigmin without benefit. She was finally stabil-

TABLE I.—RESULTS OF SURGICAL INTERVENTION IN MYASTHENIA GRAVIS

Author	No. cases	Gross pathology	Results		
			Improved	Unimproved	Died
Shumacher and Roth 1913	1	Thymus large 49 grams	1		
Haberer 1917	1	Thymus involuted	1		
Adler 1937	1	Benign tumor 12 cm.			8 days mediastinitis
Obiditsch 1937	1	Benign tumor 6 cm.			5 days streptococcus infection
Blalock et al. 1939	1	Benign tumor 6 cm.	Well after 4 years		
Campbell et al. 1941	2	Benign tumors in both	1		1, 2nd day
Blalock et al. 1941	6	Thymus large in all. No tumors	3	2	1
Poer 1942	1	Malignant tumor	1		
Turnbull 1942	1	Malignant tumor 7½ 4 cm.		1	
Clagett 943	6	Tumors in 5 Persistent thymus 1	2	2	2 questionable
Bradshaw 1943	3	Tumor in 1 Thymus large one Fatty tissue one	1	2	
Total	24	No. tumors 13	11		

ized on 15 milligrams of oral prostigmin 6 times daily and 1½ milligrams hypodermically before each meal. She was also given 4 milligrams of glycine 4 times daily and 15 milligrams of ephedrine every 3 hours. On this regimen she remained very weak, but was able to sit up some in the mornings and felt much stronger than previously. Because the patient was unable to remain ambulatory in her present situation, an exploration of the anterior mediastinum was decided upon in the hope that some thymic abnormality could be found.

On September 25, 1942, under intratracheal cyclopropane, ether, and oxygen anesthesia, an exploratory anterior mediastinotomy was carried out. The mediastinum was entered through an angular incision, extending from the hyoid region down the midline of the sternum to the third interspace, and then through the right sternal margin. The sternum was split in the midline with a Gigli saw, and the anterior thirds of the right first, second, and third ribs, and a portion of the sternum were retracted laterally, thus exposing the upper third of the mediastinum. A careful exploration was carried out from the level of the hyoid bone as far down as the cardiac auricle. The large vessels were exposed, and a careful search was made for the thymus gland. At several suggestive areas, extensive dissection was carried out, but frozen sections revealed only fatty tissues. The patient's postoperative course was not remarkable, and she was discharged on the 10th postoperative day. She was kept in an oxygen tent for a period of 24 hours immediately after operation and given several blood transfusions. She was given 1 milligram of prostigmin hypodermically every 3 hours until she had fully reacted from anesthesia, and within a period of 24 hours resumed the former dosage of prostigmin, glycine, and ephedrine.

The condition of the patient was last evaluated on March 6, 1943, at which time she stated that she was much improved and could stay up from 9:00 a.m. until 9:00 p.m. without requiring any rest period. She had continued to take between 8 and 11 15-milligram tablets of prostigmin daily during her waking hours. Her weakness was more pronounced in the mornings and required prostigmin before getting out of bed. The prostigmin had been taken only as needed by the patient, and she stated that she could often go 5 hours without any medication. On this dosage there was no further diplopia, dysphonia, or dysphagia. Ergographic tracings, compared with those taken prior to operation, revealed no improvement.

CASE 2. S.P., aged 42 years, white male, a millworker, was first admitted to the medical service on June 12, 1942, with symptoms of 3 months' duration. The symptoms of blurring of vision in the left eye upon sustained use was usually relieved by resting. He also noticed some dysphagia and dysphonia, the dysphagia progressing to the point of strangling upon the ingestion of liquid material. The weakness progressed and involved the extremities to the extent that by mid-morning the strength of his legs gave way, resulting in his collapse to the floor.

At the time of admission the patient was able to chew only a few mouthfuls of food, had periods of complete loss of voice, and was unable to hold his head erect.

Physical examination revealed a temperature of 37.2 degrees C., pulse 80, respiration 18, and blood pressure 140/96. The general physical examination was essentially normal throughout. The positive neurological findings were as follows: There was a ptosis of the left upper lid. There was a paralysis of the right lateral rectus muscle. There was definite

weakness in the neck muscles, and there was marked tiring on the performance of any continuous muscular effort. The deep reflexes were moderately hypoactive throughout, but the abdominal reflexes were normal. Examination of the eye grounds revealed nothing remarkable and the gait and station were not disturbed in any specific way. However, there was motor weakness affecting all parts of the body. The sensory function was normal throughout.

Accessory clinical findings revealed the urine to be entirely normal. Blood hemoglobin was 105 per cent; red blood count 5,300,000; white blood count 9,500 with a normal differential. Lumbar puncture revealed the spinal fluid to be normal throughout. The spinal fluid and blood Kahn were negative. Visual fields were full throughout. Skull plates were negative. The initial examination of the chest films were interpreted as showing an enlarged lymph node in the right hilar region.

During his 12 day stay in the hospital it was found that the right lateral rectus paralysis was much improved in the early morning. A diagnostic dose of prostigmin methylsulfate, 2.5 milligrams subcutaneously resulted in definite improvement in the voice, swallowing, disappearance of the ptosis and diplopia, the beneficial effects lasting from 2½ to 3 hours. Ergographic tracings made prior to and following the injection of prostigmin also showed a marked increase in strength. Also intra-arterial prostigmin methylsulfate with a manometer cuff in place resulted in the typical myasthenic response. The use of guanidine hydrochloride in the relief of symptoms was unsuccessful. He was stabilized with 15 milligrams of prostigmin bromide 3 times daily, and with oral tincture of belladonna. He was also given 1,350 roentgen units of x-ray therapy in fractional doses over anterior neck and upper mediastinum.

He was admitted to the hospital for the second time on October 3, 1942, his prostigmin bromide having been gradually increased to 15 milligrams every 2 hours, in an effort to control his symptoms. He had also been given ephedrine apparently without effect. He had gained 10 pounds in weight and his general health had been unchanged. It was interesting to note that at times the prostigmin had been ineffective when taken shortly after meals.

His physical examination was essentially unchanged, and in spite of the fact that the patient had been under the influence of prostigmin when seen there was a slight right abducens palsy and moderate tiring on the performance of any motor function. Neurological examination was otherwise normal.

Ergographic studies were carried out which showed the decreased efficiency of prostigmin taken after meals was due to decreased absorption of the drug.

During his 25 day stay in the hospital he was given a 3 hour ether anesthesia without any apparent effect on the severity of his myasthenic symptoms. This was done because of the possibility that the beneficial effect reported from thymectomy might be due to the anesthetic agent's effect on the acetylcholine and cholinesterase imbalance.

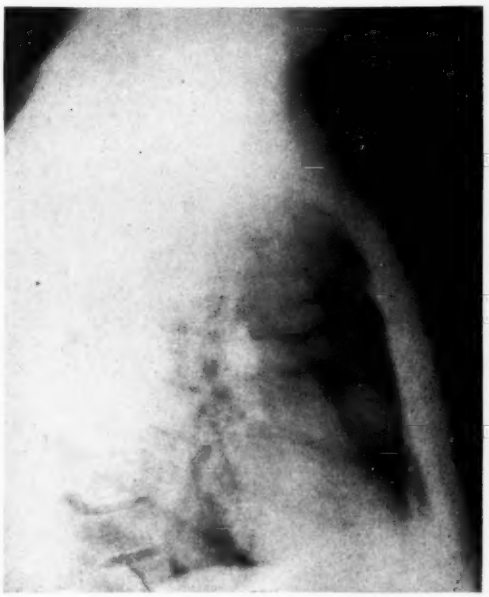

Fig. 1. Case 2. Tumor present in lower third of mediastinum.

He was readmitted to the surgical service on November 24, 1942, for surgical intervention. At this time he was taking 100 milligrams of prostigmin bromide daily and was still unable to do any work. Repeated chest films at this time with 200 cubic centimeters of air injected into the anterior mediastinum revealed the previously described lymph node to be a discrete tumor approximately 5 centimeters in diameter at about the level of the fifth costochondral cartilage (Fig. 1). Obviously, the previous x-ray therapy was not directed at this area.

On December 1, 1942, under intratracheal cyclopropane, oxygen, and ether anesthesia an exploratory mediastinotomy was done. Essentially the same approach was used as in Case 1. A well developed thymus gland occupying its normal position in the upper strait of the anterior mediastinum was first removed. It measured 8 by 2½ by 1½ centimeters. Identification of the tissue was made by frozen section at the operating table. Exploration at the level of the sixth costochondral junction on the right revealed a well circumscribed encapsulated tumor lying against the base of the aorta, and incorporating part of the right anteriomesial mediastinal pleura. It was removed *in toto*.

The postoperative course was rather stormy, marked by two "sinking spells" on the 2nd postoperative day due to an inadequate dosage of prostigmin. His temperature reached 38.8 degrees C., and the chest film confirmed the clinical impression of a right lower lobe pneumonitis, with some widen-

Fig. 2. Case 3. Preaortic tumor.

ing of the mediastinum. However, he responded readily to increased dosage of prostigmin and sulfadiazine. He was discharged on the 15th postoperative day with ½ of a 15 milligram tablet of prostigmin 2 or 3 times daily.

On his fourth admission to the hospital on February 13, 1943, his symptoms of myasthenia gravis were much improved. He was able to resume his former occupation, but was taking approximately 30 milligrams of prostigmin bromide daily. However, he had developed classical signs and symptoms of peptic ulcer, those of hunger, epigastric pain, food, and relief. He was found to have slight ptosis of the right eyelid, with a definite lateral rectus palsy on the right. The mediastinotomy scar was well healed. There was point tenderness to pressure in the deep epigastrium. His blood calcium level was 11.1 milligrams per cent. His blood phosphorus was 4.4 milligrams per cent. His stool examination was negative for occult blood. His vital capacity was 5,400 cubic centimeters. Gastric analysis revealed 9 degrees of free acid before histamine stimulation and 12 degrees after histamine stimulation. The chest film was not remarkable; the anterior mediastinal tumor seen before operation had been satisfactorily removed. A gastrointestinal study revealed marked pylorospasm with a persistent deformity of the duodenal cap. The roentgen impression was that of nonobstructing duodenal ulcer. The ergographic tracings compared with those preceding operation showed a definite improvement on less prostigmin; the response to intra-arterial prostigmin was still definitely myasthenic in character. He was given a bland diet, frequent feedings, antispasmodics, and amphojel.

He was again seen in the outpatient department on June 1, 1943, with a history of massive hematemesis, with associated tarry stools. He admitted that he had not followed his ulcer regimen. He had been working full time as a truck driver. He continued to have bouts of weakness approximately 1 to 2 hours after his noon meal which were not affected by oral prostigmin. He refused admission to the hospital.

He was seen again on June 30, 1943, and his condition remained *status quo*. He continued to have tarry stools and occasional bouts of diarrhea. His prostigmin requirement was 4 to 5 15-milligram tablets daily.

He was readmitted on July 9, 1943, for further study. Ergographic tracings revealed the ineffectiveness of his oral prostigmin following his noon meal. This was overcome by the use of the soluble form given subcutaneously.

Re-examination of the chest by fluoroscopy showed the lung fields to be clear. No mediastinal nodes were seen. There was slight narrowing of the intercostal spaces on the left, with evidence of an old pleurisy in the costophrenic angle. The heart and aorta appeared normal. No evidence was seen of a recurrence of the mediastinal tumor. His basal metabolic rate was minus 4 per cent. His glucose tolerance curve (5 hour test) was entirely normal. On this admission to the hospital, the patient was extremely unco-operative, and he admitted that he probably would not stay on his ulcer regimen. He was last seen in the outpatient department on August 5, 1943, when he was taking approximately 45 milligrams of prostigmin bromide daily (less than half preoperative requirement). There were clinical signs of a severe secondary anemia, and he gave a story of passing repeatedly large tarry stools. He refused to follow his diet or to be admitted to the hospital for further study and therapy.

Case 3. M.O.L., white female, aged 39 years, a farmer's wife was admitted on May 3, 1943, with a history of onset of symptoms of weakness of the jaw, dysphagia and syphonia, in March, 1942. The symptoms were transitory and mild and lasted only a month to 6 weeks. However, these same symptoms returned in March, 1943, with a typical story of good strength in the morning, becoming progressively weaker during the day. In addition, she had noticed drooping of the left eyelid, and blurring of vision after use of the eyes. The symptoms progressed until she noticed that after swallowing a few times she would regurgitate liquid material through her nose. She was unable to assume the sitting position without help.

On physical examination the patient was found to be fairly well nourished and there was a definite nasal accentuation of the voice. The extraocular movements were fairly well performed, there was

some definite impairment of convergence. There was no noticeable ptosis of the lids. The patient tired easily on counting or any other repeated activity requiring muscular co-ordination. The heart and lungs were clear. There was no increase in retromanubrial dullness. The reflexes were active and equal throughout. There were no pathological toe signs. The patient was unable to raise her head and sit up in bed without help.

Accessory clinical findings were not remarkable. Red blood count was 4,800,000. Hemoglobin was 15 grams. White blood count 11,000, with a normal differential. Blood cholesterol was 220 milligrams per cent. The blood Kahn was negative. Her basal metabolic rate was plus 6 per cent. The x-ray films of the chest after the injection of 200 cubic centimeters of air into the anterior mediastinum revealed a small rounded lobulated shadow at the root of the right lung, anterior to the root of the aorta (Fig. 2). There was some question as to whether the shadow was due to a mediastinal tumor or a dilated aorta. Test doses of prostigmin revealed a marked relief of symptoms as attested to by ergographic tracings made before and after the use of the drug. The intra-arterial prostigmin test, using 0.5 milligrams of prostigmin methylsulfate was equivocal. There was initial paresis with 3 or 4 fasciculations, but in a period of 3 or 4 minutes there was marked increase in strength in the tested arm. The preoperative drug requirement was finally established at 60 milligrams of prostigmin bromide daily, supplemented with 20 milligrams of ephedrine.

On May 25, 1943, an exploratory mediastinotomy was carried out. The same anesthesia was used as in the previous cases. However, the surgical approach was altered somewhat, in that the right third rib was removed by subperiosteal resection. The anterior mediastinum was then opened along the right anterolateral margin. The mass of tissue measuring 6½ by 3 centimeters, which appeared well encapsulated and of thymic origin, was removed from the anterior surface of the descending aorta. An excellent exposure of the anterior mediastinum was obtained and a careful search was made for further thymic tissues.

The patient's postoperative course was entirely uneventful; she was discharged on her 14th postoperative day. At the time of discharge she was receiving approximately 5 milligrams of prostigmin bromide 3 times daily before meals.

The patient was seen in the outpatient department on June 29, 1943, complaining of weakness and anorexia. She had been unable to stay out of bed over 3 hours at a time. However, her dysphagia and dysphonia had disappeared. She was taking 7½ milligrams of prostigmin bromide 3 times daily. The dosage was increased to 3 15-milligram tablets daily.

She was last seen in the outpatient department on September 8, 1943, some 14 weeks after operation. She continued to have extreme generalized weakness, having to spend the afternoons in bed. Appetite had improved, but diet was confined to soft foods because of excessive tiring with chewing in spite of prostigmin 30 minutes before meals. She still exhibited the tendency to "climb on herself" upon getting up from the examining table. There was a mild ptosis of the left lid and loss of convergence. Her prostigmin was again increased and potassium salts added to her medication.

In Case 1 there was no definite thymic tissue removed and certainly no objective improvement in the status of the patient's myasthenia gravis. In the light of our experience in the location of the tumor in Case 2, a more thorough search of the lower third of the anterior mediastinum would seem to be indicated. This is particularly true when one considers the wide variation in location of aberrant thyroid tissue. Remnants of thymic tissue have been removed from all levels of the anterior mediastinum as well as the neck region. Foster Kennedy studied 8 consecutive cases of myasthenia gravis at postmortem examination and found no frank tumors, but in 5 cases there was a paper-thin sheet of thymic tissue covering the pericardium.

In Case 2, prior to operation, the roentgen therapy was confined entirely to the anterior neck region, and therefore, certainly could not have covered the area of the tumor lying under the fifth and sixth costochrondral cartilages. This therapy was given before demonstration of the tumor by the air injection. It is interesting to note that the focus of attention was directed toward the superior rather than the anterior mediastinum where the thymus is thought to be more commonly located. However, it has been previously pointed out by Blalock *et al.*, that the thymus is situated almost exclusively in the thorax rather than the neck.

The result in this patient is extremely difficult to evaluate because of the development of an acute duodenal ulcer complicated by severe repeated hemorrhages. The patient was very unco-operative, refusing to follow his diet or to consider any operative procedure. In spite of his severe secondary anemia he continues to have a good range of activity on less than half of his preoperative requirement of prostigmin.

The tissue removed from this case consisted of an essentially normal thymus measuring 8 by 2.5 by 1.5 centimeters. The flattened,

TABLE II.—PATHOLOGY IN 132 CASES OF MYASTHENIA GRAVIS

	No.	Per cent
Enlargement or persistence	31	23.5
Benign tumors	38	29.0
Malignant tumors	4	3.0
Pathological change	73	55.5
No pathologic change	59	44.5

Figures include autopsies and operations

kidney-shaped tumor was entirely separate, lying 5 to 6 centimeters below the lowest portion of the thymus as a discrete, well encapsulated mass measuring 9½ by 8 by 4 centimeters. On cut section the surface had a soft brownish appearance with considerable fat tissue scattered uniformly throughout the tissue. Numerous large dilated blood vessels could be seen just beneath the capsule. At the lower pole there were 2 small cystic areas from which light yellowish fluid could be expressed. The microscopic structure of the tumor was that of large irregular areas of cell proliferation of the reticulum cell type. The cells varied greatly in size with prominent nucleoli, but no mitotic figures. Scattered throughout the tumor were diffuse collections of thymocytes. Dr. Robert P. Morehead, pathologist, was of the opinion that the tumor was benign and could be classified only as a thymoma.

In Case 3 the history of a long remission was more suggestive of a hyperplasia of the thymus rather than an actual tumor. The specimen removed consisted of a mass of tissue measuring 6.5 by 3 centimeters, weighing 10 grams, and was well encapsulated. Upon cut section the central portion of the surface had a sclerotic, cystic appearance. Microscopically, the tissue studies revealed normal thymic tissue composed of thymocytes and reticular cells. Hassall's corpuscles were numerous. The striking feature was a large fibrotic area which presented some areas of necrosis. The pathological diagnosis was incomplete involution of the thymus.

SUMMARY

A summary of the literature on the value of surgery in proved cases of myasthenia gravis has been given; approximately 50 per cent of these patients have shown improvement. To the literature have been added 3 cases in which improvement was noted in 1 and no improvement in the 2 others. We agree with previous authors on the subject that the relationship of the thymus to myasthenia gravis will be more clearly determined after careful correlation of the clinical findings, pathological changes in the gland, and the postoperative results in a larger group of patients over a period of several years.

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A SET OF NEEDLES FOR SUTURING THE RENAL PARENCHYMA

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THE purpose of this paper is to describe a set of needles of new design for suturing the renal parenchyma, and also to describe a suturing technique for which they were constructed. No particular claim for originality is made. The needles are of the "open-eye, needle-in-handle" type and employ an old suturing principle. The suturing technique combines certain principles of Deming's suture for closing nephrotomy incisions (1) and Vest's interlocking suture for obliteration of the prostatic fossa after perineal prostatectomy (2). This particular suture is intended primarily for a hemostatic suture in partial nephrectomy, calycectomy, or division of fused kidneys, but is useful in the closure of certain nephrotomy incisions. In this paper I am concerned only with the technical aspects of the procedure and shall present no animal experiments or clinical cases.

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The needles (Fig. 1) are constructed of stainless steel and their shafts are made in three shapes, one straight, one a segment of a circle 5.5 inches in

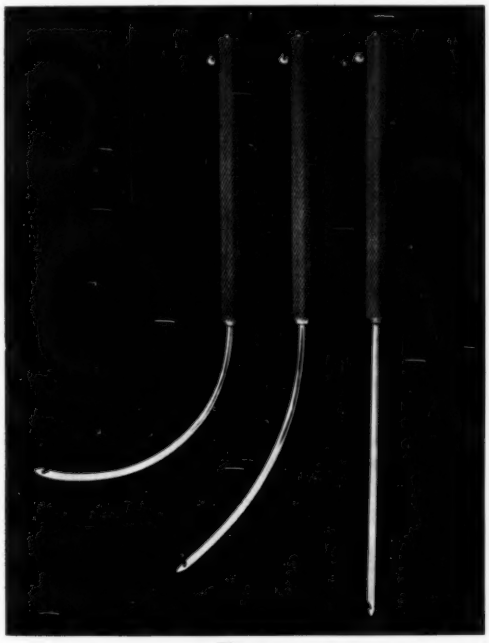

Fig. 1.

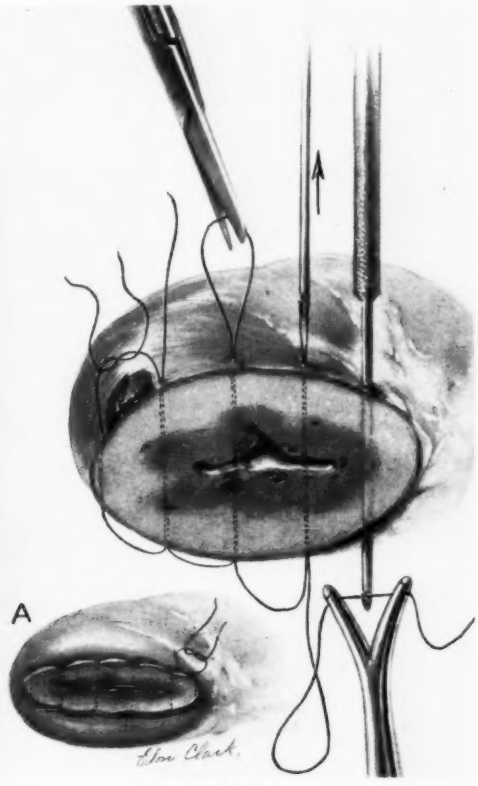

Fig. 2.

Fig. 1. Set of open-eye needles in handle of different shapes for suturing renal parenchyma.

Fig. 2. Technique of placing hemostatic sutures in partial nephrectomy. Conveniently long segments of a full length suture are introduced with the special needle at appropriate intervals along the incision, as illustrated. Division of the resulting loops of the suture provides a series of hemostatic mattress sutures which of necessity include the entire cut edge of parenchyma. Inset A shows sutures tied. Preservation of capsule to cover defect, use of muscle in order to prevent cutting, and other steps are omitted for sake of clarity.

diameter, and one a segment of a circle 2.5 inches in diameter. A small projection near the base of the knurled handle marks the position of the needle's eye. The shaft of the needle is rigid, measuring 2 inches in length and 1/16th by 1/32nd of an inch in diameter, and is abruptly pointed to minimize injury to parenchymal blood vessels. A slot on the concave margin of the needle 1/16th of an inch from the tip is of such caliber as to secure and withdraw a strand of No. 1 chromic catgut.

The suturing technique is well illustrated in the drawing (Fig. 2). An appropriately shaped needle is inserted at one end of, and close to, the parenchymal incision. The needle is thrust from capsule into pelvis in closing nephrotomy incisions (or through capsule of the opposite side of the kidney in partial nephrectomy, as in the illustration). One end of a full length of No. 1 chromic catgut is placed in the needle's slot by means of a ligature carrier, and withdrawn. The needle is then similarly reintroduced 1 to 1.5 centimeters further along the edge of the incision. The approximate junction of the first and second quarter-lengths of the suture is secured in the needle's slot and withdrawn. The resulting loop is subsequently divided providing the first quarter-length of the suture as a ligature for the first centimeter of the parenchymal incision. Additional convenient lengths of the suture are similarly placed every 1 to 1.5 centimeters so as to include the entire cut edge of kidney in successive ligatures. Additional lengths of catgut are used, if necessary.

This technique of suturing presents several advantages. It is possible to place the ligating sutures very accurately and closer to the cut edge of the kidney than is possible with the usual curved needle. This reduces the amount of renal tissue destroyed by ischemia. Technically, the suturing can be accomplished more rapidly and easily than is possible when either straight or curved needles with sutures attached are employed, as no sutures have to be introduced from the deep, less accessible surface of the kidney. Furthermore, hemostasis should be absolute as the adjacent limbs of the successive ligatures are in apposition and the entirety of the parenchymal incision is of necessity included in the row of sutures.

The straight needle is usually employed for suturing as it permits the most rapid and accurate placement of sutures. The curved needles are used when, because of limitation of exposure, one end of the parenchymal incision is not easily accessible to the straight needle. If a wedge-shaped or curved resection of one pole of the kidney is performed, one of the curved needles may allow placement of the sutures closer to the cut edge of the kidney and thus be preferable to the straight one.

Although originally designed for use in the suturing technique herein described, the needles may be used for placing almost any interrupted or continuous suture in the renal parenchyma when the usual method of suturing is difficult because of lack of exposure.

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THE RAPID IDENTIFICATION OF THE CLOSTRIDIUM WELCHII IN ACCIDENTAL WOUNDS

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GAS gangrene and tetanus are the most dreaded infections complicating fresh accidental wounds. The latter has been successfully controlled by the prophylactic use of tetanus antitoxin, and the use of toxoid gives additional promise. For several reasons the use of gas gangrene antitoxin has not been as effective, and merely its use will not prevent gas gangrene.

Gas gangrene is feared so much as a wound complication principally because it is not recognized until the lesion is far advanced. The wounds in which gas gangrene is prone to develop are extensive ones, and their treatment requires the use of large dressings, casts, or splints. These coverings make observations indirect and deductions difficult and uncertain as to the progress of events within the wound. Gas gangrene may develop insidiously beneath the cast and may not be recognized until 48 to 72 hours have elapsed. Once the lesion is sufficiently established to permit a diagnosis from the clinical appearance of the wound, a far advanced and often irreversible process is present. Such delay is costly and results in extensive incisions, unnecessary amputations, and even death. For these reasons, we have attempted to formulate some plan of management of wounds contaminated with gas bacilli which will prevent delayed diagnosis and its tragic consequences.

Gas gangrene is a clinical entity of multiple bacterial etiology. A great variety of gas-producing anaerobic bacteria, chiefly the Clostridium welchii, Clostridium sporogenes, Vibrion septique, Clostridium oedematiens and Clostridium histolyticus, have been repeatedly found in association with this condition. The individual case usually presents a mixed bacterial flora of aerobes as well as anaerobes. The fact remains, however, that the Clostridium welchii is the principal cause of gas gangrene and is present either alone or in association with other gas-producing anaerobes. It was found in 72 to 80 per cent of the cases of gas gangrene studied (3) in the World War and has since been consistently found in civilian cases in this country. In the present war, the Clostridium oedematiens has been found in association with gas gangrene on some battlefields, but the Clostridium welchii continues to play an important etiological rôle.

The number of gas bacilli contaminating a wound conceivably may be small. Diagnostic smears usually are of little value, particularly if they are taken in less than 12 hours after receipt of the injury or if bleeding is present. The results of anaerobic culture of material swabbed from fresh contaminated wounds are not as accurate as those of tissue débrided from the wound. Careful anaerobic cultures will demonstrate the presence of the Clostridium welchii or other gas gangrene producing bacteria, but such anaerobic analysis is of no immediate value to the surgeon because of the specialized technique required and the long time consumed by such examinations. A means of rapid cultivation and simple identification of the Clostridium welchii in tissue débrided from wounds should be of considerable value to the surgeon.

The most characteristic known cultural peculiarity of the gas bacillus is its stormy fermentation of milk in 18 to 48 hours under anaerobic conditions (2). Using representative strains of Clostridium welchii which we isolated from accidental wounds, we have studied this reaction as

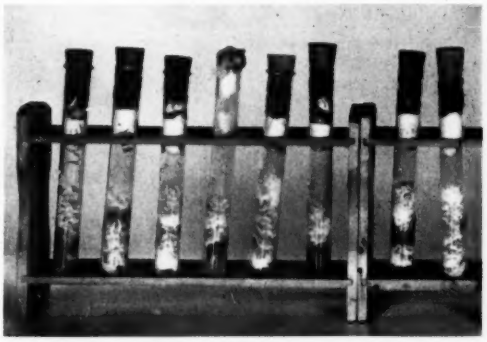

Fig. 1. Showing typical stormy fermentation reaction developing within 7 to 7½ hours from culture of contaminated muscle, débrided from experimental wounds. Series XIII, March 6, 1941. Bacillus welchii. Dilutions 10^{-7}; dose, 0.5 cubic centimeter. Wounds excised in 2 hours.

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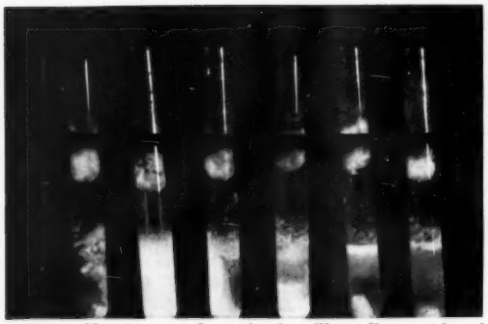

Fig. 2. Shows types of reaction in milk medium produced by the culture of Bacillus welchii and other clostridia commonly found in wounds. The Bacillus welchii culture is 24 hours old; all others are 5 days old. From left to right, tubes contain B. welchii, B. novyi, Vibrion septique, B. putrificus, B. histolyticus., B. sporogenes.

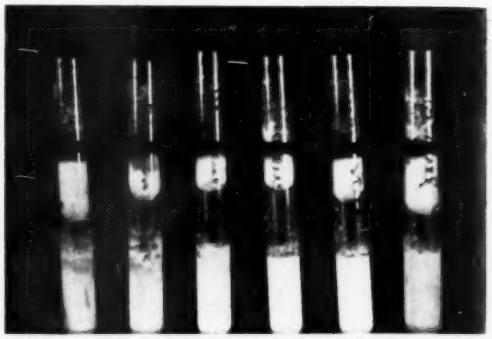

Fig. 3. Reactions produced by the aerobic bacilli of colon group and the anaerobic bacillus melaninogenicum and streptococcus. Compare reaction given by Bacillus coli and Aerobacter aerogenes with that given by Bacillus welchii. From left to right, tubes contain B. coli-is. B. coli-ior, B. aerogenes, B. proteus, anaerobic strep., B. melaninogenicum.

to its limitations and possibilities for application to the direct culture of débrided contaminated tissue.

The usual time required for the stormy fermentation of autoclaved litmus milk was 18 to 36 hours with these cultures. This is too long to be of much practical importance surgically. After considerable experimentation, it was found that the speed of this reaction could be greatly increased. The fermentation of the milk is dependent upon the amount of lactose available for bacterial action. A good grade of fresh milk was found to be superior to a poorer grade in which part of the lactose had been converted into lactic acid by the action of such bacteria as the Streptococcus lactis. Sterilization by autoclaving caramelizes lactose, and this probably explains the superiority of milk media sterilized by heating for 1 hour in a dry oven at 120 degrees C. on 3 successive days. Separation of the cream also aided the reaction. The use of any indicator such as litmus not only delays the stormy fermentation, but is unnecessary in that the differential characteristic is the type of coagulum produced. For this reason we have omitted all indicators. The time required for the reaction is greatly decreased by the addition of fresh and crushed muscle tissue. Finally stormy fermentation will occur under aerobic conditions in preheated and cooled milk which has been inoculated with the Clostridium welchii, but not as rapidly nor as typically as under anaerobic conditions. Our method of anaerobiosis is a modification of Wright's method (2) using pyrogallic acid and Rockwell's solution (1). We have found this

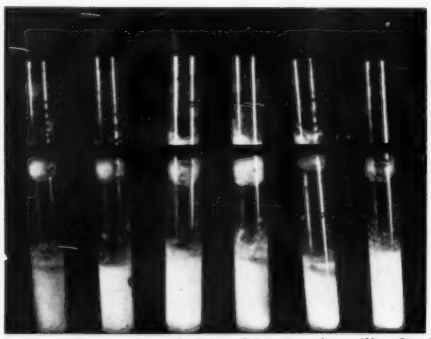

Fig. 4. The results of the cultivation in milk of other bacteria commonly found in accidental wounds is shown. From left to right, tubes contain Staph. aureus, Staph. albus, Strep. hemolyticus, Strep. viridans, Nonhemolytic Strep, B. subtilis.

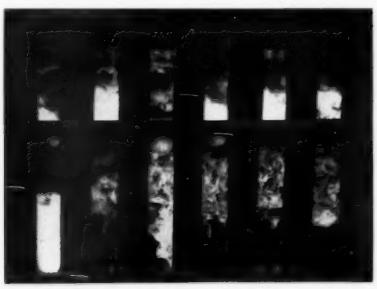

Fig. 5. Showing typical "stormy fermentation" of milk by culture of muscle débrided from contaminated human wounds. Note the character and position of the coagulum and the 3 missing rubber corks which have been blown off by the evolution of gas. Positive test for Bacillus welchii 5 hours after débridement, May 13, 1941.

method simple, convenient, efficient, and practical for this purpose. With our present technique of media preparation and anaerobic cultivation, a typical stormy fermentation is produced in 4 to 10 hours, depending upon the inoculated dose of Clostridium welchii, as compared to 18 to 48 hours when autoclaved or desiccated litmus milk was used.

A series of controlled experiments were then conducted in guinea pigs. Under the strictest aseptic conditions, 58 wounds 1 centimeter in length were made through the skin and muscle of the medial thigh or paraspinal region of guinea pigs. The exposed muscle in each wound was then crushed exactly 10 times with a hemostat to devitalize that tissue. Into each wound was placed 0.5 cubic centimeter of a saline dilution up to 10^{-7} of an 18 to 24 hour brain broth culture containing a known number of living Clostridia welchii. This number was determined by plating and incubating for 72 hours 0.5 cubic centimeter of the same diluted suspension at the time of the inoculation of the wound. The number of viable gas bacilli introduced into these wounds varied between 3 to 120. The wounds were then closed by approximation of the skin edges with fine black silk sutures. After intervals of 1 to 5 hours the wounds were excised and all débrided tissue was placed into the preheated and cooled milk medium and incubated anaerobically. Typical stormy fermentation occurred promptly in 4 to 10 hours even when as few as 3 living gas bacilli were originally inoculated into the wound (Fig. 1).

Twenty-eight controls made under identical conditions excepting the inoculation with Clostridium welchii, all gave negative reactions except 1 when the excised tissue was introduced into the milk. In spite of our precautions, the 1 control wound became cross-contaminated by Clostridium welchii from the guinea pig's hair and skin.

Unless each wound was made with the strictest aseptic technique and carefully controlled, false results were obtained. The hair, skin, and feces of the guinea pig normally contain Clostridium welchii, and wounds made without aseptic precautions invariably became cross-contaminated. In our preliminary experiments consisting of 62 wounds not made under aseptic conditions, we had learned that a positive stormy fermentation reaction was given both by the wounds we inoculated and by the controls.

When débrided muscle contaminated with Clostridium welchii is incubated anaerobically in this medium the reaction is very typical (Fig. 1). Active gas formation may be observed early, sometimes within 2 or 3 hours, due to the rapid fermentation of the lactose. As the gas formation becomes more intense, coagulation of the milk occurs. The coagulum rapidly becomes contracted and riddled with holes by the gas, and within 5 to 10 hours there is complete separation of clot from whey. The differential characteristic of the reaction is the irregular shrunken coagulum which is floating on top of, or adherent to, the side of the culture tube above the level of the clear whey. The whey has the offensive odor of butyric acid and shows marked hemolysis of the blood introduced along with the débrided muscle. Such a reaction controlled by the examination of hanging drop and stained smear preparations, we believe to be indicative of the presence of Clostridium welchii.

A study of other bacteria isolated by us during the past 1½ years from contaminated wounds has failed to show any bacterium, either aerobic or anaerobic, which gives an identical reaction (Figs. 2, 3, 4).

While this reaction is typical of Clostridium welchii, some strains of Clostridium butyricum or Clostridium multifermentans may approach or almost equal it in intensity. To find either of these bacteria in a wound would be unlikely, and we have found no report of their presence in wounds. However, if an examination of a stained smear and hanging drop of the whey at the height of the reaction shows the predominant microorganism to be a gram positive nonmotile bacillus, the presence of Clostridium welchii is established since the Clostridium butyricum and Clostridium multifermentans are both motile.

It is true that the active gas-producing aerobes, Bacillus coli, and Aerobacter aerogenes, may produce active fermentation and coagulation of milk, but the reaction is easily distinguished from that of Clostridium welchii. It is much slower, and if it does become sufficiently strong to cause separation of the coagulum and whey, the loose coagulum settles to the bottom of the culture tube and is covered with whey not having the offensive odor of butyric acid. All of the strains of Clostridium welchii isolated from human wounds gave typical and rapid stormy fermentation reactions in the milk medium.

During the past 2½ years we have used this method successfully at the Cincinnati General Hospital for the rapid detection of the presence or absence of Clostridium welchii in over 600 contaminated and infected accidental wounds and it has been of value in the early diagnosis of gas gangrene while the infection is still in the incipient or localized stage (Fig. 5). Whenever the gas bacillus is detected in tissue débrided from a

traumatic wound, the patient is placed under close observation for the development of the earliest symptoms of gas gangrene. Roentgen examinations (1) for gas in the soft tissues are done at the slightest suspicion of trouble. Serial films taken at 2 to 4 hour intervals aid in the differentiation of gas due to mechanical causes from that due to the gas bacillus. If the gas increases in amount or presents a linear spread, a diagnosis of gas gangrene can be made. In this manner a diagnosis of incipient or early gas bacillus infection can be made long before one is possible by the clinical findings alone permitting early and effective surgical treatment.

SUMMARY

The stormy fermentation of milk has been studied and found to be specific for the Clostridium welchii when controlled by the examination of hanging drop and stained smear preparations of the whey. We have been able to increase the speed and intensity of this reaction to such an extent that a typical reaction will occur within 5 to 10 hours or less.

The media found to be most satisfactory for this purpose can be made as follows:

A good grade of fresh pasteurized milk is boiled for 5 minutes and allowed to cool in a refrigerator for 8 to 12 hours. The supernatant cream is removed by siphonage and the remaining milk is placed into culture tubes, 6 to 8 cubic centimeters per tube being used. Sterilization is accomplished by heating the milk in a dry oven on 3 successive days at 120 degrees C. for 20 minutes. Indicators, strips of stove pipe iron, and enriching substances are not used. The tubes of media are kept in the refrigerator close to the operating room so that they are readily available at the time of operation.

The possibilities of the stormy fermentation of milk as a means of quick and accurate detection of Clostridium welchii in fresh accidental wounds have been explored. When pieces of muscle débrided from contaminated experimental human wounds were placed in suitable media, a typical reaction occurred in 5 to 10 hours. The method as described has been successfully used by us to detect accurately and quickly the presence of the gas bacillus in contaminated or infected accidental wounds and to aid in the early diagnosis and treatment of gas gangrene.

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MARCH FRACTURES OF THE TIBIA AND FEMUR

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DURING combat and especially during basic training periods, the incidence of march fracture[1] has become a rather significant entity. As one reviews the literature, there is little doubt that no bone of the lower extremity is exempt from this type of injury.

An excess of current literature can be found covering march fractures of the foot; however, reports of tibial and femoral march fractures are in the minority. Our purpose in this report is to present the clinical, laboratory, and roentgenological aspects of 7 tibial march fractures and 1 femoral march fracture encountered in a 3 month period at the Station Hospital, Camp Reynolds, Greenville, Pennsylvania. It is interesting to note that this series includes the fourth reported case of an identical bilateral march fracture of the tibiae (6).

The necessity of universal recognition of tibial and femoral march fractures can be readily appreciated when one realizes the various misdiagnoses which are often "tagged" to this condition. The most common misdiagnoses are: Garré's sclerosing osteomyelitis, periostitis, osteogenic sarcoma, bone syphilis, and tuberculosis of bone. Pfahler reported one insufficiency fracture of the tibia and included 2 similar cases presented by Hanson which were primarily misdiagnosed as osteogenic sarcoma. We should heed his warning as to the danger of such a diagnosis. Roberts and Voight reported a series of 15 cases of so called "pseudo-fractures" of the femur in children between the ages of 4 and 16 years which included 3 cases reported by Weaver and Francisco. These authors concluded that they were dealing with a nonsuppurative form of osteomyelitis and proposed it as a new entity. In the light of our present knowledge, however, we are inclined to believe that what they have described are typical march fractures of the femur.

Complete clinical digestion of our 7 cases of tibial march fractures evolved the following significant findings:

1. Body type and age incidence. Patient was usually of the tall, fair, Nordic type. The age average was 19 years and 8 months; the youngest being 19 and the oldest 22.

2. Mode of onset. The mode of onset in every instance was sudden pain in the upper tibia followed by lameness. These symptoms always occurred during exercise such as sustained marching, double timing, or obstacle course running.

3. Laboratory findings. The basal metabolic rates and blood counts in each case were within the accepted normal range. The serum phosphatase was within the upper limits of normal. The serum calcium was consistently low and the serum phosphorus slightly elevated. Blood Kahn tests were negative.

4. Roentgenological aspects. The roentgenological aspect of tibial march fractures can be best outlined by indicating the constant findings that are seen on the serial roentgenograms. The diagrams in Figure 1, composites of our series of 7 tibial march fractures, clearly illustrate the stages which are present in these cases. Figure 2 illustrates the late 3d stage illustrated in these diagrams.

TREATMENT

Therapy consisted chiefly of palliative physiotherapy and cessation of all forms of forced exercise such as drills, hikes, and obstacle course runs. Immobilizing casts were not applied to the affected lower extremity, and the patient was not hospitalized. Calcium therapy was not used in our cases.

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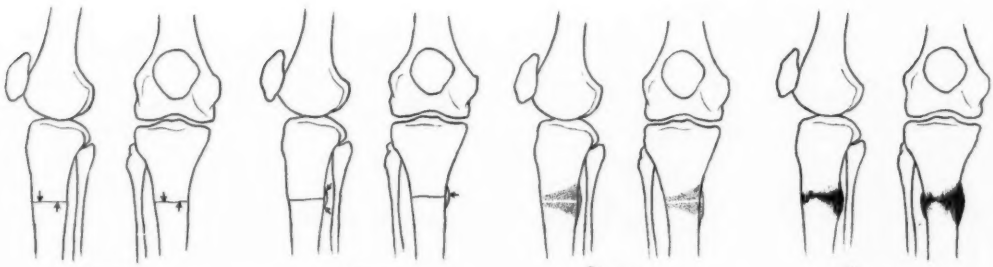
[1] Synonyms are: shoveler's, creeping, exhaustion, insufficiency, overload or spontaneous fractures (8). Deutschlander's *Krankheit, Marschgeschwulst, Fussgeschwulst, Marschfraktur, fracture de recrue, pied débile, pied force, pied de marche, l'enflure du pied, pied surcharge* (17).



Stage 1. Stage 2. Stage 3. Stage 4.

Fig. 1. Stage 1. Time: seen in the first week following the sustained march fracture. X-ray criteria: A fine horizontal fracture line is seen through the upper shaft of the tibia, about 10 centimeters from the knee joint.

Stage 2. Time: seen in the second week following the sustained march fracture. X-ray criteria: A very slight amount of callus is seen at the medioposterior cortical fracture site. The callus is first seen in this position because it is the point of greatest weight bearing stress. The fibula splints the lateral fracture site which probably accounts for the lack of callus at this point.

Stage 3. Time: seen in the third week following the sustained march fracture. X-ray criteria: A band of bone condensation is seen at the fracture site and bone absorption at immediate fracture line. Parallel cortical callus is present at medioposterior cortical fracture site. Callus is sometimes seen at the lateral fracture site during this stage.

Stage 4. Time: Seen in the fourth week up to the twelfth week following the sustained march fracture. X-ray criteria: Cortical callus and bone condensation is increasing. Fracture line has disappeared. After the twelfth week the callus begins to absorb.

THE MECHANICS OF MARCH FRACTURE FORMATION

Ingersoll, in his excellent paper "Ice Skater's Fracture, a Form of Fatigue Fracture" (fatigue fractures of the lower fibula), pointed out that a rhythmical mechanical stress at the point of greatest bone bending was the salient factor in the production of this type of fracture. In reference to fatigue fractures (march fractures) he stated: "It has been shown that such lesions tend to occur at the site of greatest bending of bone and this is determined by the forces acting upon it." In summarizing this type of fracture Ingersoll reiterated: "Ice skater's fracture belongs in the group of fractures occurring insensibly in seemingly normal bones and resulting from the summation of microtraumas due to repeated mechanical injury." These principles of Ingersoll can be aptly applied to the mechanics of tibial and femoral march fracture formation. The rhythmical mechanical stress was the alternate thrust of the body weight down each leg during each step. The tibia and the femur were rhythmically bent anterolaterally with each step and the microtraumas occurred at the sites of greatest bone bending which in this instance was at the upper shaft of the tibia and the lower shaft of the femur. When the saturation point of microtraumas was reached, usually after sustained marches, a complete fracture in the tibia or femur occurred.

REPORT OF CASES

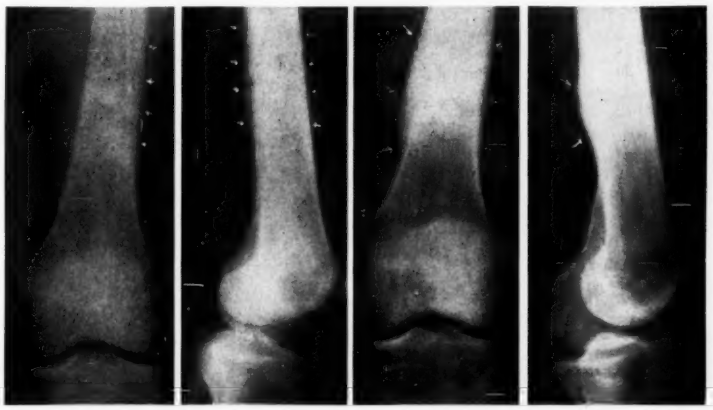
CASE 1. L. M., age 19 years, an air cadet at Allegheny College, Meadville, Pennsylvania, presented himself at the orthopedic clinic at Camp Reynolds, Pennsylvania, on July 17, 1943. The patient stated that on July 7, 1943, during a 3 mile trot he experienced a sharp pain in the upper left leg which became worse the following morning. Pain continued in this location but the cadet continued his duties. Several days later he experienced pain in the upper right leg after a 200 yard run at moderate speed.

Roentgenograms taken on July 17, 1943, demonstrated a slight degree of periosteal callus at the medial cortex of both tibiae about 10 centimeters down from the knee joint. Careful scrutiny of these roentgenograms revealed fine transverse fracture lines extending through the full thickness of both tibiae at the level of the callus. The diagnosis of bilateral tibial march fractures was rendered and the patient was placed on a restricted exercise regimen plus palliative physiotherapy. Serial roentgenograms taken at weekly intervals revealed healing of the fractures which conformed to the stages illustrated in Figure 1.

On October 2, 1943, that patient was asymptomatic and complete healing of the fractures had taken place. Full duty was permitted at this time.

Laboratory findings were consistent with those described in the clinical discussion.

CASE 2. J. C., age 19 years, infantryman, was first seen in the orthopedic clinic at Camp Reynolds, Pennsylvania, on June 16, 1943, at which time he was complaining of dull pain in the lower left thigh. He stated that he experienced a sudden sharp pain



a b

Fig. 2.[1] Case 2. a, Roentgenograms taken on June 16, 1943 demonstrated parallel cortical callus of a slight degree, which could have been misinterpreted as an early Ewing's tumor. b, The film records of August 30, 1943 showed a marked degress of callus and bone condensation. This had the appearance of sclerosing osteomyelitis.

[1] The roentgenograms reproduced in this paper were made in the photographic department at the U. S. Army Medical Museum, Washington, D. C. The negative numbers are: 76523; 76527; 76528; 76529; 76531; 76533.

in the lower left thigh on May 19, 1943, while marching during training maneuvers in Texas. This pain became progressively worse and on the following day he was unable to get out of bed. He was excused from all activity during the next 3 days.

Roentgenograms of the left femur, which were taken upon return to his regular station in Texas, were declared negative. (It may be stressed at this point that these micro fractures are not always visible on early roentgenograms and the x-ray diagnosis of a march fracture cannot be made until a subsequent roentgenogram reveals a slight degree of periosteal callus.)

Fig. 3. Roentgenograms illustrating a tibial march fracture in the late third stage. Note the cortical callus and the bone condensation along the radiolucent fracture line. Its likeness to an osteogenic sarcoma is striking.

Patient continued to have pain in the lower left thigh upon his arrival at Camp Reynolds, Pennsylvania, on June 16, 1943. Roentgenograms of the left femur taken on that day and on August 20, 1943, are presented in Figure 2. The x-ray diagnosis of a left femoral march fracture was rendered.

This patient was placed on limited duty immediately and received palliative physiotherapy. He was symptom free by the end of July and was placed on full duty.

SUMMARY

1. A series of 7 tibial march fractures and 1 femoral march fracture are reported.

2. As far as we could determine from perusal of the literature our case of a bilateral march fracture of the tibiae was the fourth of its kind to be reported. More of these cases would be discovered, we believe, if comparison roentgenograms of both tibiae in suspected march fractures were made.

3. The site of fracture, symptoms, and laboratory findings were found to be constant.

4. The application of stage x-ray criteria would prevent unwarranted misdiagnoses such as Garré's sclerosing osteomyelitis, periostitis, osteogenic sarcoma, Ewing's sarcoma,

bone syphilis of the tibia, and tuberculosis of bone.

5. The mechanics producing these types of march fractures are discussed.

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VARIATIONS OF THE FEMALE SACRUM

Their Significance in Continuous Caudal Anesthesia

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THE ingenious method of continuous caudal anesthesia was introduced into the field of obstetrics by Hingson and Edwards in January, 1942 (4). Since this date numerous reports have acclaimed its success, and cumulative experience would seem to indicate that this procedure constitutes a very definite advancement in the management of labor and delivery (2). The administration of continuous caudal anesthesia may present at least one technical difficulty: the insertion of a malleable needle through the sacral hiatus into the sacral canal. The increasing application of this method of anesthesia, both in obstetrics and in general surgical procedures, makes it exceedingly important for the clinician to have a working knowledge of the anatomical conformation and of the more common structural modifications of the sacrum in its mid-dorsal region and especially of the sacral hiatus.

It is the purpose of this paper to record and depict certain anatomical features and structural variations of the female sacrum, not only that some of the isolated past failures in the administration of continuous caudal anesthesia may be explained but more particularly that they may be prevented in the future. Observations and measurements were made on the sacra of 674 white and negro females. Of the bones studied 328 are a part of the Terry Anatomical Collection (Washington University) and 346 a part of the Todd Anatomical Collection (Western Reserve University)[1] whose means of documentation and method of preparation have been described (1, 8).

OBSERVATIONS

The hiatus canalis sacralis may be defined as the termination of the sacral canal. It lies between the sacral cornua where the laminae of the fourth and fifth sacral vertebrae are incomplete. Thus, in viewing the sacral hiatus from its dorsal aspect it presents usually a somewhat triangular outline with the apex extending cephalad to the level of the lower third of the body of the fourth sacral vertebra and the base caudad to the level of the middle of the body of the fifth sacral vertebra. However, the hiatus of the sacral canal is variable in extent and form.

Certain dimensions obtained on the present series serve to provide a concept of the general configuration of the hiatus. The mean width of the base of the hiatus of the sacral canal is 16 millimeters. There is a range from 7 millimeters to 28 millimeters or a total variation of 21 millimeters. The length of the hiatus from the base to the apex has a mean of 19 millimeters and varies from 0 millimeters to 66 millimeters. A sacrum with a typical hiatus canalis sacralis is shown in Figure 1a.

The anteroposterior diameter of the sacral canal at the level of the apex of the hiatus is on the average 5.3 millimeters with a range from 0 millimeters to 16 millimeters. In 5.5 per cent of the series this diameter was 2 millimeters or less (compare Figs. 1b and 10b).

The apex of the hiatus is classically described as occurring at the level of the lower third of the body of the fourth sacral vertebra. In this series, however, it is located at this level in only 35 per cent. In 20 per cent of the cases the apex is found at various points below this region and in the extreme cases extends as far caudally as the lower border of the body of the fifth sacral vertebra. In the remaining 45 per cent the apex lies at planes cephalad to the lower third of the body of the fourth sacral vertebra; the highest level is at the lower third of the body of the second sacral vertebra or at the union of the bodies of the second and third sacral vertebrae (Fig. 2).

Variations in the structure of the dorsal wall of the sacral canal are numerous. It may be open throughout its entire length and 2 examples of that type are found in the Western Reserve University series. However, sacra are frequently seen in which the superior extent of the dorsal wall of the canal does not extend cephalad as far as the level of the inferior border of the body of the first sacral vertebra. This results in an increased distance between the laminae of the fifth lumbar and the bony dorsal wall of the sacral canal and a reduced distance between the supe-

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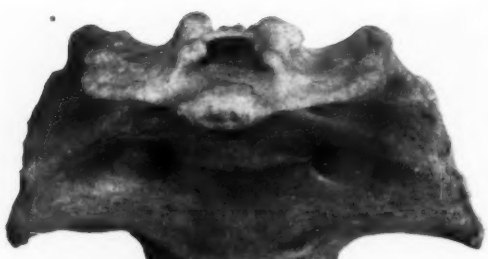
Aided by a grant from the U.S. Public Health Service.

[1]Dr. Normand L. Hoerr, professor of anatomy, Western Reserve University, kindly granted us the privilege of using the Todd skeletal collection.

a



b

Fig. 1 W.U. 51R. a, Hiatus canalis sacralis of typical dimensions. b, Sacral canal with average anteroposterior diameter at the apex of the hiatus.[1]

rior limit of the dorsal wall of the canal and its hiatus. Such a condition may be the result of low-lying laminae of the first sacral vertebra (Fig. 3) or of a deficient development of the laminae of the first or even of several of the superior sacral vertebrae (Fig. 4). In some cases the dorsal wall of the sacral canal presents a deficiency somewhere between its superior and inferior limits; this deficiency may be unilateral, bilateral, or found in the midline, or it may be

[1]The photographs for this figure and for succeeding figures were made by Mr. M. B. Rhoades of the Department of Anatomy.

Fig. 2 W.U. 1353R. A long hiatus in which the apex reaches the level of the union of the bodies of the second and third sacral vertebrae.

seriated as a result of a deficiency of development and subsequent union of the laminae and spines of adjacent vertebrae (Figs. 3, 5, 6). The distance from the apex of the hiatus to such apertures or to low-lying laminae was noted. It is 70 millimeters or less in 22 per cent (148 sacra); 50 millimeters or less in 10 per cent (69 sacra); and 20 millimeters or less in 2 per cent (13 sacra).

The lumen of the sacral canal or the hiatus itself may be obliterated or partially blocked by at least two types of variation which are of opposite character. One type gives the appearance of a transverse fold in the dorsal wall of the canal and is associated with a forward projection of the body of the vertebra just cephalad to the level of the compression (Fig. 7). This condition in the dorsal wall may and usually does completely obliterate the lumen of the canal where it occurs. Ten sacra of this series present such a fold or compression; in 7, it extends between the second pair of posterior sacral foramina, and in the remainder, it lies between the third pair of posterior sacral foramina. The second type of variation is the result of a backward or dorsalward projection of the body of a vertebra into the sacral hiatus or canal (Fig. 8). It usually occurs either in a markedly curved sacrum and the projection is a constituent of the curve or in a straight sacrum with the first coccygeal vertebra fused at an angle approaching 90 degrees.

Lastly, there may be present an overgrowth of bone obliterating the hiatus and extending the

Fig. 3 W.U. 822. A long hiatus; an aperture between the laminae of the first and second sacral vertebrae; and low-lying laminae of the first sacral vertebra.

dorsal wall of the sacral canal inferiorly (Fig. 9a); the lumen is unaffected (Fig. 9b) but the normally palpable landmarks are masked. This variation is pronounced in only one bone of the series.

DISCUSSION

In order to provide a basis for certain deductions which may be drawn from the main anatomical features and structural variations that have been described, it is advantageous to review the configuration of the average hiatus of the sacral canal (Fig. 1). Among the 674 female sacra considered the typical hiatus canalis sacralis is 16 millimeters wide at the base and has a height of 19 millimeters; the apex lies at the level of the lower one-third of the body of the fourth sacral vertebra. Of these features the one most pertinent to the problem of caudal anesthesia is the height of the hiatus; this is obviously the determining factor of the level of the apex in relation to the bodies of the vertebrae. A long hiatus essentially reduces the distance between its apex and the inferior limit of the subarachnoid space (Figs. 2, 3, and 6). Like dimensions may be found in hiatuses of varied contour. Thompson, in a paper entitled, "An Anatomical and Experimental Study of Sacral Anesthesia" included photographs depicting the various shapes of the hiatus—triangular, horseshoe, curve, irregular, and staple—which he encountered in 38 sacra present in the anatomical laboratory of the University of Texas at the time of his study. The

Fig. 4 W.U. 562. Deficient development of the laminae and spines of the first and second sacral vertebrae.

sacra of the present series also present a variety of contours but no variation in outline was encountered which could be construed as important in the technique of continuous caudal anesthesia.

Although the sacral hiatus may vary in extent and form without obstructing the entrance of a needle, the anteroposterior diameter of the sacral

Fig. 5 W.U. 1160. Bilateral apertures in dorsal wall of sacral canal.

Fig. 6 W.U. 306. Apertures in the midline of the dorsal wall of the sacral canal between laminae of the first and second sacral vertebrae and between laminae of the second and third sacral vertebrae; also, a long hiatus.

canal at the level of the apex of the hiatus is of prime importance in the technique of the administration of caudal anesthesia. Indeed, it may be the determining factor for entrance of a needle into the sacral canal after it has pierced the superficial posterior sacrococcygeal ligament. The mean diameter of this aperture is 5.3 millimeters (Fig. 1b). In 5 bones the dorsal and ventral bony

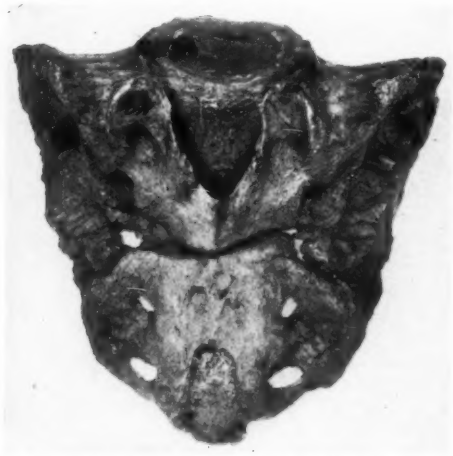


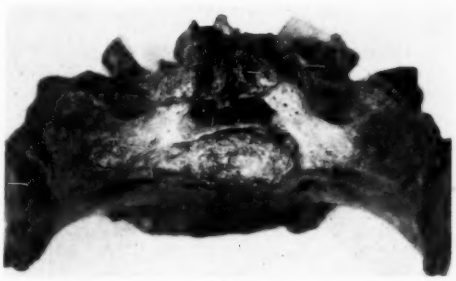
Fig. 7 W.U. 480. A condition simulating a transverse fold in the dorsal wall; the sacral canal is occluded.

Fig. 8 W.U. 24R. a, Protrusion of the body of the fifth sacral vertebra dorsalward into the sacral hiatus; the first coccygeal vertebra is fused to the fifth sacral at an angle approaching ninety degrees. b, Shortened anteroposterior diameter of the sacral canal at the level of the apex of the hiatus, the result of the dorsalward protruding vertebral body.

walls of the sacral canal were completely fused at the level of the apex of the hiatus; in 36 bones (5.5 per cent) the measurement was 2 millimeters or less (Fig. 10). Furthermore, in the recent or living state this diameter may be appreciably decreased by the presence of the periosteum and the posterior longitudinal ligament. The needle which is recommended as most suitable for this procedure is a No. 18 or 19 gauge stainless steel malleable needle. It becomes evident, therefore, when all of these factors are taken into consideration that on a purely mathematical basis it may be extremely difficult or indeed impossible to insert even a No. 19 gauge needle into the canal in a small percentage of patients.

In those sacra with canals of such diameter that permit with ease the introduction of a No. 18 or

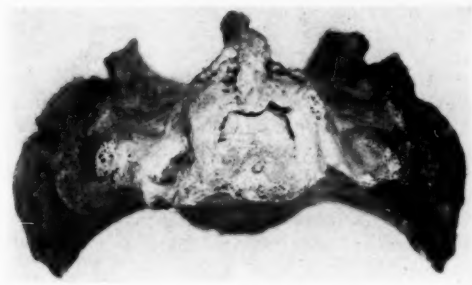
a



b

Fig. 9 W.U. 1078. a, Bony overgrowth obliterating the hiatus and extending the dorsal wall of the canal caudally. b, Anteroposterior diameter of the sacral canal unaffected by the bony overgrowth.

a



b

Fig. 10 W.U. 1526. a, The hiatus canalis sacralis viewed dorsally exhibits no unusual features. b, The sacral canal viewed through the hiatus presents at its caudal limit an anteroposterior diameter of only 1 millimeter.

19 gauge needle the hiatus may be completely blocked or so reduced as to make the insertion of the needle impossible. One such example consists of a dorsal protrusion of the body of a lower sacral vertebra into the hiatus or canal (Fig. 8). Also, there may exist a condition simulating a fold which completely occludes the canal (Fig. 7). Certain features of this latter variation are suggestive of spondylolisthesis, which is usually described as occurring in the lumbar region of the column. This variation is present in 10 of the specimens, a small incidence, but nevertheless, a significant clinical feature when encountered.

The dorsal wall of the sacral canal is not infrequently open to a greater degree than is normally anticipated. Several general types of dorsal wall agenesis are described in this paper and may be listed as superior or inferior laminar deficiencies and unilateral, bilateral, or midline apertures (Figs. 3, 4, 5, and 6). "The more common formations and anomalies of the sacrum" depicted by Southworth, Hingson, and Edwards (7) in a series of drawings made from the skeletal collection in the Museum of Anatomy at Jefferson Medical College present examples of dorsal wall deficiencies. Hingson and Edwards have included similar illustrations in their article entitled "Comprehensive Review of Continuous Caudal Analgesia for Anesthetists" (6).

The importance of dorsal wall agenesis is directly related to the fact that after the special caudal needle pierces the superficial posterior sacrococcygeal ligament it is of necessity "depressed almost to a level with the body plane, and its point directed upward exactly in the midline, following the axis of the canal for a distance of 1½

to 2 inches'' (4). The presence of any unexpected aperture may permit the point of a dorsally directed needle to escape the canal and thus result in the subcutaneous deposition of the anesthetic agent (Fig. 6). Since, "The needle should be inserted within the canal for a distance of about 5 to 7 cm." (3), the distance from the apex of the hiatus canalis sacralis to a superior deficiency or a unilateral, bilateral, or midline aperture is of real clinical significance. This distance is 7 centimeters or less in 22 per cent of the sacra included in this study. In 2 per cent of the sacra this distance is 2 centimeters or less (Fig. 5).

In the administration of continuous caudal anesthesia, "The tip of the coccyx is palpated with the middle finger of the left hand, and the thumb is used to find the U or V shaped notch indicating the sacral hiatus between the sacral cornua. This is usually about 1½ or 2 inches from the tip of the coccyx" (5). The clinician must, nevertheless, be well aware of the fact that the guiding anatomical features may be completely disguised or alleviated by bony overgrowths and projections. The sacrum depicted in Figure 9 well illustrates how such a growth may totally mask the hiatus although the canal may be of even greater than average diameter. Indeed in this case the anteroposterior diameter of the canal is 6 millimeters (Fig. 9b).

Numerous other minor variations might be cited which under certain circumstances could conceivably impede the introduction of the special continuous caudal anesthesia needle into the hiatus canalis sacralis. It has been the purpose of this paper, however, to limit the material presented and the features discussed to those factors which anatomically and statistically seemed to be of special clinical importance and thus warrant the careful consideration of the practicing obstetrician and surgeon.

SUMMARY

Variations in the anatomy of the mid-dorsal region of the sacrum and their significance in the administration of continuous caudal anesthesia were studied in a series of 674 female bones.

1. In 45 per cent the hiatus canalis sacralis reached a level on the sacrum cephalad to the level of the lower third of the body of the fourth sacral vertebra. This condition reduces the distance between the highest possible point of entrance of the needle into the canal and the inferior limit of the subarachnoid space.

2. In 22 per cent deficiencies existed in the dorsal wall of the sacral canal which might permit an exit of the needle. This would result in the injection of the anesthetic agent into the surrounding soft tissues.

3. In 5.5 per cent the anteroposterior diameter of the sacral canal at the level of the apex of its hiatus was 2 millimeters or less. The insertion of a No. 19 gauge needle into such a canal is difficult if not impossible.

4. Other variations include obliteration of the lumen of the sacral canal and masking of the palpable landmarks in the region of its hiatus.

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THE INCIDENCE OF LIVER STONES ASSOCIATED WITH CHOLELITHIASIS AND ITS CLINICAL SIGNIFICANCE

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THE incidence of cholelithiasis in adults, as proved by various autopsy studies and examination of cadaver material, is probably between 20 and 30 per cent. Graham, Cole, Copher, and Moore, in their textbook concerning the gall bladder, placed the figure between 20 and 25 per cent of all adults. Carter, Greene and Twiss, in a more recent textbook, noted a similar figure. Mentzer reported 26.6 per cent in 633 autopsies. Hektoen and Riesman found calculi at autopsy in 25 per cent of all cadavers after the 60th year. Hansen of Norway quotes a percentage of 24.7 in 392 autopsies.

The high incidence of common duct stones in cases of cholelithiasis has been fully appreciated only during the last 15 years. In the past, continued or recurrent biliary distress following cholecystectomy has too frequently been attributed to liver dysfunction, hepatitis, cholangitis, pancreatitis, or partial injury to the common duct, when as a matter of fact it was due to a stone in the common duct. In 1928, Wilkie emphasized the frequency of common duct stones in cases of cholelithiasis by reporting 47 patients with stones in the common bile duct in a total of 256 operated upon for cholelithiasis (18 per cent). This was followed in 1930 by Clute's enlightening and interesting report that he had explored the common duct in 15 per cent of a series of cases, and had found common duct stones in 8.4 per cent. In another series, he had opened the common duct in 35 per cent of the cases, finding that the incidence of common duct stones increased correspondingly to 17.9 per cent. Lahey reported that the common duct was explored in 40 per cent of a series of patients between 1930 and 1935, and stones were found in 18 per cent. Crump, in a series of 1000 routine autopsies, reported 325 with gallstones, 78 (24 per cent) of these having stones in the biliary ducts. In my last 100 consecutive cholecystectomies, 33 common ducts were opened (33 per cent), and common duct stones were found in 17 of these (17 per cent). As one analyzes the figures of various authors, it would seem that the common duct should be explored in 20 to 40 per cent of all cholecystectomies, and that stones will be found in about one-half of the ducts opened. In other words, in 1 of every 4 or 5 cases of cholelithiasis, stones will be found in the common duct. The usual criteria for opening the duct have been a history of jaundice, palpable stones in the common bile duct, a dilated common duct, a thickened common duct wall, small stones in the gall bladder, or thickening of the head of the pancreas.

Regardless of how frequently choledochostomies are performed or what technique is used, I believe that sooner or later every surgeon will encounter 1 or more cases in which he feels satisfied in his own mind that the common duct has been thoroughly explored and all stones and débris removed, only to find out later at a necessary secondary operation that another stone is present. There is no doubt that there are elusive stones in the common duct, especially at the lower end where at times they seem to seek a small diverticulum or pocket and avoid the exploring forceps, probe, or irrigator. Again, stones may form from minute particles of débris or precipitate in the choledochus.

However, I believe that there is another very definite source of so called recurrent or remaining common duct stones, which, as one peruses the literature, he finds is seldom mentioned. I refer to stones which are present in the liver at the time of the original operation and which, for one reason or another, become dislodged from the intrahepatic ducts following cholecystectomy, and give rise to symptoms. It is entirely plausible that some of these stones are dislodged by factors associated with opening the common duct, such as manipulation of the duct, changes in intraductal pressure, and irrigation of the duct. In other instances, it is possible that the freeing of the lower end of the common duct permits free egress of bile. Again, the time element may be the only factor.

By examination of the autopsy records of the usual hospital—be it a charity, teaching, private or clinic type of institution—one is unable to arrive at a significant or accurate conclusion as to the incidence of liver stones, for, in the routine autopsy, examination of the liver consists merely of weighing the organ and describing its appearance, color, and consistency after 3 or 4 slices are

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TABLE I.—INCIDENCE OF LIVER STONES IN CHOLELITHIASIS

Cases of cholelithiasis	Cases of liver stone	Incidence Per cent	Author	Year reported	Country
Not given	Not given	5.0	Thudichum	1863	Germany
Not given	Not given	9.0	Schroeder	1892	Germany
72	6	8.3	Beer	1904	Germany
257	20	7.7	Miyake	1913	Japan
97	7	7.2	Hansen	1926	Norway
30	2	6.6	Best	1943	U.S.A.
456	35	7.4 *			
		7.6†			

*Average of all percentages
†Average excluding first 2 groups.

made through its substance. Until this investigation was begun, on no occasion had I seen the liver sliced thin enough that all intrahepatic ducts were opened so that any stone resting in a duct could be identified. Later, however, this procedure was carried out in 30 cases of cholelithiasis, and in 2 of them stones were found within the intrahepatic ducts.

In 1 of these instances, a middle aged woman from whose common duct I had removed a stone, a delayed cholangiogram taken 9 days after operation had revealed a remaining common duct stone. Following the second operation, for removal of this remaining stone, the patient died. Examination of the liver by the method here described revealed 2 stones in the ducts of the right lobe of the liver and 1 stone in a duct of the left lobe.

The other case was that of a woman who had died of a cardiovascular disturbance. Autopsy revealed many small stones in the gall bladder and a few stones as well as considerable thick débris in the common duct. This patient had given no history of jaundice but did have a long history of severe indigestion and rather sharp upper quadrant distress. Careful examination of the liver revealed a single stone in a duct of the left lobe of the liver.

The finding of liver stones in these 2 cases in a group of 30 cases of cholelithiasis gave an incidence of 6.6 per cent. This stimulated me to attempt to confirm what seemed a fairly high incidence of liver stones. Although a rather extensive search was made in the literature for reports of liver stones, I have made no attempt to report on the subject of single cases of liver stone, but have merely attempted to find evidence to support my own figures on the incidence of such stones and to arrive at some definite conclusion which might be of clinical value in the problem of the so called recurrent or remaining common duct stone.

According to Rufanov, isolated cases of liver stones were reported in the 16th and 17th centuries. In 1863, Thudichum, quoted by Beer (2), stated in his treatise on gallstones that 5 per cent of all patients with cholelithiasis had stones in the liver. Courvoisier, in 1890, collected the cases in the literature to that date, 50 in number, but in his lengthy discussion of hepatolithiasis did not give the relative frequency. In 1890, Schroeder, quoted by Beer (2), reported that intrahepatic concretions were present in 9 per cent of his cases. However, like Thudichum, he drew his conclusions from autopsy notes and did not state the number of cases he had examined. In 1904, Beer (1, 2) reported in both American and German literature his findings of biliary pathology in 250 autopsies in which the entire liver ductal system was carefully examined for stones. Of these 250 cases, 72 had cholelithiasis, 6 with stones in the intrahepatic ductal system. In 5 of these cases, the stones were rather large and in the 6th there was considerable gravel in the liver ducts. This gives an incidence of 8.3 per cent of stones within the liver in cases of cholelithiasis. In 1913, Miyake of Japan reported on 8,400 routine autopsies. There were 257 cases of cholelithiasis which he examined thoroughly for liver stones. Of these, 20 had intrahepatic duct stones, an incidence of 7.7 per cent. Miyake collected these cases from 3 different pathologico-anatomic institutes. There were 191 cases of cholelithiasis from Tokyo, 13 of them with liver stones; 35 cases from Kioto included 1 with liver stone; 31 cases from Kinschu with 6 cases of liver stones. Rufanov, in discussing this article by Miyake, stated that liver stones were more frequent in Japan but it would seem the higher incidence depended rather upon the method and thoroughness of the search for stones. In 1926, Hansen of Norway reported on 392 autopsies with 97 cases of cholelithiasis. Careful examination of the liver in these cases revealed 7 with stones in the intrahepatic ducts, an incidence of 7.2 per cent. In 1936, Rufanov thoroughly discussed the subject of liver stones in an excellent article and, as quoted before in this thesis, he stated that hepatolithiasis was of rare occurrence according to data from the pathological institutes of Russia, but again it must be emphasized that the method of examining the liver was probably inadequate. He reviewed considerable literature and, although he again reported and discussed many isolated cases in addition to 5 cases of his own, under no circumstances could one arrive at the incidence of liver stone in cases of cholelithiasis. His lengthy

article was written with the hope of arriving at some conclusion regarding the diagnosis of hepatolithiasis, the type of treatment most satisfactory, the pathological picture, and to clear up some questions on the pathogenesis of gallstone disease as a whole.

In an analysis of the figures presented, we find that the average incidence of liver stones is 7.4 per cent (Table I). If we include only those figures which show the number of cholelithiasis cases with the number of cases in which liver stones were found, we have a more accurate analysis. In total, there were 456 cases of cholelithiasis with 35 cases of liver stone, an incidence of 7.6 per cent (Table I). This figure seems rather high for the incidence of liver stone in cholelithiasis, but is substantiated by the fact that each group of cases examined revealed a similar figure.

As to the source of liver stones, it is possible they are dislodged from the gall bladder into the common duct and then carried into the intrahepatic ducts, or they may form within the liver ducts themselves. If stasis, infection, and metabolic disturbances are considered as etiologic factors of stone formation within the gall bladder, the fact that fewer stones are found in the liver could be based entirely upon the fact that bile stasis is less common in the liver than in the gall bladder. That gallstones may develop in the ductal system is somewhat substantiated by the fact that Rufanov reports a case described by Leopold in which a common duct stone was found and removed when there was a congenital absence of the gall bladder. He refers to a similar case reported by Finkelstein, and in this instance the common duct stone recurred. According to various investigators, the composition of stones found in cholecystolithiasis, choledocholithiasis, or hepatolithiasis seems to have the same variation as stones from the gall bladder.

Hepatolithiasis may be classified as follows: (1) isolated stones within the ducts; (2) ducts packed with stones, gravel or a pasty, cement-like débris; (3) stones imbedded in a cavity containing a collection of bile or pus; (4) an existing purulent cholangitis with multiple small abscesses containing stones or gravel. I have seen cases of the first 2 types.

Surgical attacks upon liver stones have been limited because of the difficulty of diagnosis as well as the technical difficulty of the surgical approach. I have reveiwed many cholangiograms but have never seen one revealing a stone within the intrahepatic ducts, although I have heard this described. On a number of occasions, I have felt that evidence was sufficient to prove that the stones revealed in the common duct by delayed cholangiograms following careful choledochostomy had their origin in the liver. The most significant example of this was one of several cases previously described (3, 4) in a discussion of nonoperative management of remaining common duct stones. The delayed cholangiogram revealed 11 common duct stones. At the time of operation on this thin patient, the common duct was easily accessible; it had been opened and thoroughly explored but no stones were found. Upon examination of the cholangiogram on the 8th postoperative day, it could only be concluded that this number of stones could not have been missed at operation but had come down from the liver. In the article referred to, the 3 day biliary flush is advocated as a means of removing common duct stones and débris has succeeded in 25 per cent of such cases.

From previous studies on increasing the flow of bile and raising intraductal pressure (5), it is believed that one can safely assume the same measures would flush out stones and débris from the intrahepatic ducts into the common duct. It might be suggested that all patients subjected to cholecystectomy or any type of biliary tract operation should have the following 3-day biliary flush several days preceding operation in the hope that any intrahepatic stones would be forced into the common duct where they would be accessible at the time of cholecystectomy. Thus a secondary operation for a stone which had descended later might be avoided.

THREE DAY BILIARY FLUSH REGIMEN

1st day:

1. Decholin or procholon—3 tablets 3 times a day and at bedtime.
2. Nitroglycerin, grains 1/100, 3 times a day before meals.
3. Magnesium sulfate, 2 drams before breakfast.
4. Pure cream, 1 ounce before evening meal and at bedtime.

2nd day:

1. Decholin or procholon—3 tablets 3 times a day and at bedtime.
2. Atropine, grains 1/100, dissolved in a little water, 3 times a day before meals.
3. Magnesium sulfate, 2 drams before breakfast.
4. Pure cream, 1 ounce before evening meal and at bedtime

3rd day:

1. Decholin or procholon—3 tablets 3 times a day and at bedtime.
2. Nitroglycerin, grains 1/100, 3 times a day before meals.
3. Magnesium sulfate, 2 drams before breakfast.
4. Pure cream, 1 ounce before evening meal and at bedtime.

Animal investigation has not been carried out to prove this supposition, but removal of common

duct stones and débris by this method has frequently been demonstrated. Likewise, the routine postoperative use of the 3-day biliary flush in all cases of cholecystectomy has certainly resulted in a smaller number of postoperative biliary syndromes and lends support to the contention that the ductal system can be flushed out. As a routine measure the biliary flush is given on about the 8th postoperative day and is repeated 2 weeks later.

SUMMARY

From investigation and from available figures, it would appear that liver stones are present in approximately 7 per cent of all cases of cholelithiasis, this probably being the source of a certain number of recurrent or remaining common duct stones. It is suggested that the 3-day biliary flush be given to all patients before any biliary tract operation in the hope of flushing these liver stones into the common duct where they will be accessible at the first operation, thereby avoiding a second.

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FRACTURED PELVIS COMPLICATED BY GANGRENE OF EXTREMITY—AMPUTATION UNDER REFRIGERATION ANESTHESIA

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RARELY is the complication of gangrene of the lower extremity following fractures of the pelvis mentioned in the literature on this subject. The fact that one of the authors has had the unusual experience of helping in the management of 2 such cases within the period of approximately 1 year justifies this report. The additional fact that refrigeration of the affected extremities was utilized for a considerable period prior to amputations and that eventually the amputations were performed under refrigeration anesthesia should arouse further interest in these 2 cases.

When one considers the intimate relationship of the iliac and femoral vessels to the bones of the pelvis, it is almost inexplicable that injuries to these vessels and their branches have not been noted and reported more frequently. The same is true of the large nerve trunks which traverse the pelvis, injuries to which are seldom mentioned in the literature. Most authors, in dealing with complications associated with fractured pelves, dwell upon injuries to the bladder, urethra, and rectum and their sequelae. The fact that the blood vessels, especially the smaller branches, are very frequently injured, is borne out by the presence of hematomas of varying sizes within and without the fractured pelvis. However, the collateral circulation to the lower extremities is so rich about the pelvic girdle that rarely does interference to circulation manifest itself beyond a slight pallor or numbness in the extremity. Most of us have witnessed this phenomena without thinking of or fearing gangrene. But when a large hematoma indicative of damage to the branches comprising this collateral circulation is combined with thrombosis of the external iliac or femoral arteries, then gangrene of a major portion of the lower extremity is extremely imminent.

In the first instance, with only pallor and numbness present, one should use every available means to conserve the part until the circulation is reestablished. Wheather this can best be accomplished by the time-honored methods of wrapping the extremity in cotton-wool and applying heat, or by the newer method of slowing the demands of metabolism by refrigerating the part, will be a mooted question until time and experience have proved or disproved the value of the latter method. When the circulation to the lower extremity is so damaged that gangrene is inevitable, prevention of the moist, infected type of gangrene until the line of demarcation is established is our chief concern. Here refrigeration is far more efficacious than heat. The refrigerated extremity, provided refrigeration is adequate, soon passes into a state of hibernation. All metabolic processes, including the demand of the tissues for oxygen and blood supply, are in abeyance. The development of infection and the liquefaction of dead tissues with their accompanying toxins are likewise held in abeyance. If, as was true in one of our cases, the patient's general condition is such as to make early amputation inadvisable and dangerous, this period of hibernation can be prolonged until the patient's condition warrants amputation.

Fractures of the pelvis, when uncomplicated, are correctly considered the simplest type of major fractures to treat. When complicated they often present the most serious emergency, taxing the surgeon's judgment and ability to the limit and not infrequently end fatally. In some eight hundred cases collected from the literature, where mortality rates were mentioned, the latter varied from 8 per cent to 17.7 per cent. In 108 cases treated by the senior author, from 1922 to 1942, 9 deaths occurred from complications. Three of these fractured pelves were associated with skull fractures. The fact that the fracture *per se* is simple to treat must not lull the surgeon into complacency lest one of these serious complications be overlooked.

In a review of 5 recent textbooks on fractures, all the authors stress the complications of ruptured bladder, urethra, and rectum. Most of them refer to the possibility of intra-abdominal injuries. Scudder, and Key and Conwell each mentions the complication of fatal hemorrhage from injuries to the great vessels unless these can be exposed and ligated. Not one of these 5 authors mentions thrombosis of the external iliac

or femoral arteries followed by gangrene and the possibility of amputation.

One of us (Tannehill) made a comprehensive review of the literature on the subject of fractured pelvis covering the period from 1878 to 1943 and thereby collected 3,108 cases. In only 13 cases were injuries to the external iliac or femoral vessels mentioned. Three of these were described as lacerations of the external iliac artery; 2 as lacerations of the external iliac vein; 1 as a laceration of the femoral vein; 1 as an injury to the external iliac and femoral vessels followed by gangrene and amputation; 3 as a thrombus of the external iliac artery, 1 of these followed by gangrene and amputation; 2 as a thrombus of the femoral artery; and 1 as a gangrene of the lower extremity. Eight of these 13 patients died from the above complications. It is noteworthy that in 3,108 cases collected from the literature only 3 cases of gangrene of the lower extremity were listed and in only 2 of these cases were patients subjected to amputation, with 1 of these recovering.

Newell reports on 4 cases of fractured pelvis, 1 of which was complicated by an injury to the external iliac artery, and 1 by the fractured horizontal ramus injuring the external iliac artery. In the latter case gangrene developed in the corresponding lower extremity, necessitating amputation above the knee. This patient recovered.

Lucas describes 3 cases of fractured pelvis, 2 with lacerations of the external iliac vein and 1 with laceration of the external iliac artery. All died.

Bacon describes hemorrhage as occurring in 6 cases from tearing of the soft parts. One of these cases had a laceration of the femoral vein, the patient dying of hemorrhage.

Browne mentions a case in which the fractured superior ramus of the pubis had torn off the inferior epigastric artery at its origin from the external iliac artery. The artery was ligated but death followed 4 hours later from shock.

Moritz had 1 case in which the femoral vein was lacerated by a spicule of bone from the pubic crest. The vein was repaired by lateral suture with recovery of the patient.

Grandy reports 1 death from laceration of the external iliac artery complicating a fractured pelvis.

Magruder reports a case of oblique fracture of the right ischium with overlapping of the fragments with fracture through the right sacroiliac joint. The right lower extremity became cold, and sensation was lost. There was no pulsation in the femoral, popliteal, or posterior tibial arteries. No operative intervention was attempted. Gangrene developed and the patient died 18 days after the injury. The autopsy revealed the anterior crural nerve and the external iliac artery caught between fractured fragments and completely severed. There was a thrombus in the external iliac artery extending almost up to the common iliac.

Glen describes a fractured superior ramus of the pubis which occluded the external iliac artery by forcing it against the inguinal ligament. The latter was divided at operation and circulation thereby restored. However, the patient died on the third day of uremia.

In an article entitled "Obstruction of Arteries due to Injury" T. Bryant lists 3 cases of thrombosis of the external iliac artery associated with pelvic fracture, and in addition thrombosis of the external iliac and femoral artery due to a severe contusion without fracture. One of these, a male, aged 53 years, was seen 2 weeks following an injury sustained in a fall from a horse. There was a swelling in the right groin and the right leg was cold and numb. There was no pulsation in the external iliac, femoral nor popliteal arteries. The leg was wrapped in cotton-wool and elevated. In 6 weeks the tibial vessels were felt pulsating and in another 3 weeks the superficial femoral artery was evidently open. After convalescence no pulsation was ever detected in the external iliac or femoral arteries. In the other 2 cases of pelvic fracture gangrene developed in the lower extremity; 1 was amputated and died 11 days later, and the other died on the 3d day without amputation. Autopsies in both instances revealed the thrombosed external iliac arteries.

In a paper, not yet published, presented before the American Academy of Orthopedic Surgeons in 1943, one of the authors (Mock) described a case of fractured pelvis with tearing of the femoral artery, followed by severe hemorrhage into the thigh. This patient was in such critical condition when seen that an emergency bedside operation was performed and the femoral artery ligated. Before a blood transfusion could be administered the patient died. Mock also described a case of fractured pelvis in an elderly woman with a large dissecting hematoma down the right thigh. The hematoma was evacuated. Gangrene of the skin and fascia of the entire circumference of the lower third of the thigh, except for an area of 3 inches in width on the posterior surface, and gangrene of the skin over 60 per cent of the circumference of the knee developed. The gangrenous tissue over these areas was dissected away. The wounds were eventually closed by skin grafting.

To these 2 reported cases of gangrene of the lower extremity treated by amputation, which were found in the literature, the authors wish to add their 2 cases:

CASE REPORTS

CASE 1. B. K., aged 21 years, was caught in a milling machine and the right side of his pelvis was severely fractured. In addition a compound fracture of the proximal ends of the radius and ulna opened wide the elbow joint. He was immediately hospitalized and hemorrhage and shock were combated by transfusion and other means. The senior author was called in consultation 36 hours after this accident occurred because a paralysis had developed in the patient's right leg. Case notes on the hospital chart indicated that patient could move his right leg during the first 24 hours, but signs of paralysis had developed during the subsequent 12 hours.

Examination of the injured parts revealed a 3-inch laceration with multiple puncture wounds over the right lower abdomen, a hand's breadth above the pubis and 3 inches inside the crest of the ilium. These wounds penetrated the skin and fascia but did not enter the abdominal cavity. The upper half of the right ilium gave a sense of crepitation and looseness. There was a marked swelling suggesting a retroperitoneal hematoma inside the crest of the ilium as well as under the gluteal muscles. The right lower extremity seemed completely paralyzed. There was a definite foot-drop. Anesthesia of the entire right lower extremity was present, and temperature, tactile, and position sense were lost. Patellar and Achilles reflexes, present in the left leg, were completely absent in the right. The leg was not cold or blanched, and at this time no thought of a circulatory disturbance was considered. Rather, the consultant's entire attention was centered upon the possibility of a nerve injury either from fragments of the fractured pelvis or from an injury to the spine.

A portable x-ray examination of the pelvis, made a few hours prior to this consultation, showed the upper half of the entire right ilium completely fractured with numerous comminuted fractures through both the anterior and posterior fragments of the ilium. The lower end of the main fracture ended just above the acetabulum. Two fragments of bone were broken completely from the ilium and were pushed downward behind the greater trochanter.

The right arm was markedly swollen from the axilla to the wrist. There were severe lacerations about the elbow with evidence of multiple fractures which were shown by the portable x-ray. No further reference will be made to the arm except to mention that the presence of this severe upper extremity injury probably slowed down the treatment of the pelvic condition and added greatly to patient's extremely critical condition during the first week. The arm was saved but with much deformity at the elbow.

Shock and hemorrhage had been and were still the most alarming features present. These two conditions definitely contraindicated any radical surgery at the time of this consultation. Even in considering surgery, the severely damaged arm seemed to be the chief point of attack.

On June 27, or 9 days following consultation, the author was again called to see this patient. During the interval he had developed marked infection in both the compound fractures of the arm and in the lower abdominal wounds. Drainage had been established at both sites. The paralysis in the right leg had persisted. Two days prior to this second consultation, a slight discoloration of the right great toe was noted for the first time. The following day this bluish discoloration had involved half of the foot.

Examination showed that pulsation over the femoral and popliteal arteries was completely absent although this was said to have been present 3 days previously. Beginning gangrene of the lower extremity was evident. A fluctuating mass extended from the gluteal crease up over the entire right side of the pelvis and onto the abdomen. An immediate operation for the evacuation of this infected hematoma and the removal of the loose fragments of the ilium behind the greater trochanter was recommended, and the consultant was asked to perform the operation. It was hoped that by taking the pressure off of the collateral circulation there was a possibility that this might re-establish itself and thus check the progress of the gangrene. There was also a chance that the femoral artery had become plugged with a thrombus quite recently and this might be removed.

Operation. Under general anesthesia an incision was made over the right hip and a quart and a half to two quarts of old bloodclots and pus were evacuated. The cavity involved all of the gluteal region and extended upward along the surface of the fractured ilium onto the abdomen. This cavity was readily connected with the infected cavity at the site of the abdominal injury. Two large fragments of the ilium were displaced downward, one behind the hip joint and the other between the hip joint and the greater tuberosity. These fragments were removed. Following this procedure a second incision was made over the femoral artery and vein. Both vessels were completely thrombosed. The thrombi were organized and considerable liquefaction of the tissues about the vessels was present.

In an effort to localize the gangrene to the foot or lower extremity ice bags were packed around the foot and up to the middle third of the leg in order to refrigerate the part. No tourniquet was applied. This was one of our earliest cases of refrigeration and the ice bags were not kept filled and constantly in close apposition to the part, as has been true with subsequent cases. The black toes and bluish foot remained the same but the ankle and lower third of the leg developed a pinkish appearance, and at no time did the gangrene seem to spread and neither did a moist gangrene or infection develop. Pulsation, however, never returned in the popliteal artery or in the vessels of the lower extremity. Meanwhile, the patient's condition, the result of the extensive infection at the hip, improved. His temperature became normal. After 2 weeks amputation in the middle third of the leg was deemed advisable.

A soft rubber tube was placed about the leg, just below the knee, as a tourniquet, after the site had been refrigerated by ice bags for 1 hour to anesthetize the part. A rubber sheet was then tied about the thigh 4 inches above the tourniquet and was wrapped about the entire lower extremity as a trough. This trough was filled with two and one-half buckets of cracked ice, making positive that the ice extended above the tourniquet and surrounded the limb, including the foot. After 2½ hours of refrigeration, with tourniquet in place, amputation 6 inches below the knee was performed. No other anesthetic whatsoever, other than a drink of whisky, was used. The muscles and the fat at the site of amputation had a healthy red appearance, except for a darkened area in the gastrocnemius muscle which resembled spoiled meat, similar to that seen in a leg of beef hung in the refrigerator. Refrigeration of the stump, without tourniquet, was continued for only 2 days. A longer period of refrigeration might have avoided the subsequent development. This area in the gastrocnemius muscle broke down and developed a low-grade infection, and the gangrene spread through the posterior surface of the stump in spite of renewed refrigeration. Two weeks later, again under refrigeration anes-

thesia, a second amputation was performed through the thigh just above the knee. This stump healed rapidly and the patient's convalescence was uneventful.

CASE 2. F. S., male, aged 52 years, on February 16, 1943, sustained a crushing injury of the head, chest, and pelvis, when he was caught between the chassis of a railroad crane and a loading platform. He was admitted to St. Luke's Hospital on the service of Drs. Chivers and Tannehill, about 1 hour after injury, in a state of shock; temperature, 98 degrees; pulse, 100; respiration, 30; blood pressure, 80/66. The pulse was weak and thready, and the patient was very dyspneic.

This patient showed a dramatic picture of traumatic asphyxia. His face, neck, upper chest, and arms were very cyanotic; subconjunctival hemorrhages with edema of the conjunctiva were present, and ecchymotic areas and petechial hemorrhages soon developed over the head and neck.

Pressure over the iliac crest caused severe pain in both groins. The lower abdomen was rigid. The patient was able to move both lower extremities, but movement caused pain. Blood was noted coming from the urethra. A diagnosis of ruptured urethra in the presence of a possible pelvic fracture was made; Dr. Harry Culver passed a catheter with considerable difficulty, and it was left indwelling for 2 weeks when the lesion was healed.

Patient was placed in an oxygen tent, morphine was administered for the pain, and 250 cubic centimeters of plasma and 250 cubic centimeters of serum were given, following which the blood pressure rose to 98/70 and in a few hours to 120/85.

Portable x-ray plates of the pelvis revealed a fracture of the left ischium at the junction of the horizontal and vertical rami; a fracture through the left ischium at its junction with the acetabulum; a comminuted fracture involving the horizontal ramus of the right ischium, and a fracture of the right pubis at its junction with the acetebulum, with the fragments displaced slightly inward and upward, causing a definite deformity of the pelvic inlet.

During the next 24 hours the patient was fairly comfortable. He was still in an oxygen tent because of the marked cyanosis described. He then began to complain of pain in the right leg. All ability to move the leg was lost. The limb at this time was cold and blanched. Pulsation in the dorsal pedal, posterior tibial, popliteal, and femoral arteries was absent. Thrombosis of the right external iliac and femoral arteries was suspected.

It was at this point that the senior author was called in consultation. Unquestionably, gangrene of this entire lower extremity was inevitable unless some collateral circulation developed before such a catastrophe occurred. Refrigeration of the entire extremity was suggested as a means of lowering the demands of metabolism in this limb, of holding a moist gangrene and infection in abeyance, and of giving time for the formation of a collateral circulation if the same was possible. At any rate, we could hang this leg in an improvised refrigerator until such time as the patient's condition warranted amputation. Therefore, the entire lower extremity was placed in a large rubber sheet with ten ice bags inside this sheet and the latter then bound firmly about the limb. The situation was explained to the private nurses who kept the ice bags filled and the limb thoroughly refrigerated continuously for 2½ weeks.

Lung findings were present from time of admission and a true pneumonia was diagnosed at the end of 48 hours. His temperature rose to 103 degrees Fahrenheit, respirations 32, and pulse 120. Sulfadiazine therapy was instituted and oxygen therapy continued for 2 weeks. At no time during this period could this patient have withstood the ordeal of an amputation if the same had been demanded by the presence of a moist gangrenous infected extremity.

However, because of the refrigeration the right lower extremity remained in a very well preserved condition. The foot and ankle varied from a slightly bluish to a dusky appearance. The remainder of the leg varied in color from a blanched to a pinkish hue. A line of demarcation developed at the junction of the lower and middle thirds of the thigh. As one approached this line from the knee the color varied from a pinkish to a slightly bluish tint. Above the line of demarcation the refrigerated thigh looked perfectly normal. Still no pulsation could be felt in any of the vessels of this extremity. It is noteworthy that this extremity, deprived of all circulation at the junction of the middle and lower thirds of the thigh to the toes for a period of 19 days, at no time had developed blebs, any evidence of moist gangrene, and no sign of secondary infection. The tips of the toes alone showed evidence of a dry, leathery gangrene. On the 19th day amputation was decided upon.

On the day prior to amputation thermocouple readings were made in this refrigerated extremity in order to ascertain the temperature deep in the tissues. Similar readings were made after the tourniquet had been applied and just before amputation. These showed temperatures 1 to 3 inches below the skin varied from 32.7 degrees to 34.4 degrees Fahrenheit before the tourniquet was applied, and temperatures varying from 33 degrees to 33.5 degrees Fahrenheit after the application of the tourniquet.

At 8 a.m. March 6, a soft rubber tube was wrapped twice about the patient's thigh near the junction of the upper and middle thirds. It was placed sufficiently tight to close off all arterial and venous flow. A rubber sheet was tied about the thigh some 3 inches above this tourniquet and was then wrapped about the remainder of the lower extremity as a trough. Four buckets of cracked ice were poured into this trough and the ice thoroughly packed around the limb and foot extending well above the tourniquet. The head of the bed was elevated in order that melting ice water could escape from this trough. Cracked ice was renewed as was necessary to keep the extremity covered. Three hours later the patient was taken to the operating room and the junior author proceeded to amputate just above the junction of the middle and lower thirds without any other anesthesia whatsoever being used except three drinks of whisky. Throughout the procedure the blood pressure never varied. There was absolutely no shock from the operation. The muscles of the thigh at the site of amputation were a healthy red color. After the tourniquet was removed the vessels not yet ligated bled freely. The stump was closed tightly without drainage after installation of sulfanilamide crystals. Patient was returned to his room in excellent condition and ate a good lunch.

Following the operation patient continued to run a low-grade fever which had persisted following his pneumonia. On March 9 he began to expectorate a quantity of foul-smelling purulent material. X-ray of the chest was taken and revealed a fluid level in the midportion of the right lung which appeared to be behind the hilus. Upon returning from the x-ray laboratory the patient developed a violent attack of coughing, became cyanotic and dyspneic and suddenly brought up a large amount of pus. It seemed that he was drowning in this pus until the resident performed a hurried tracheotomy, and large quantities of the material were then aspirated through the tracheotomy tube.

On March 31 Dr. Willard Van Hazel performed a rib resection for the purpose of evacuating an empyema abscess. On April 18 patient developed still another abscess in the right groin at the site of an old hematoma. This was drained and healed a few days thereafter. The tracheotomy

wound was allowed to close on April 24. In spite of the presence in this patient of so much infection, developing so shortly after the amputation, his stump healed by primary intention with the exception of a small area 2 by 4 centimeters which sloughed. After débridement this small area healed readily. Patient was discharged from the hospital on June 5 having completely recovered from all of his wounds and their complications.

REFRIGERATION AND REFRIGERATION ANESTHESIA

Refrigeration is the chilling of tissues. Freezing damages tissues as in frost-bite; refrigeration does not. The tissues of an extremity may be refrigerated, that is, chilled, to within a few degrees of 0 centigrade for many days and still retain their viability. For example, the upper thigh, in Case 2, was refrigerated for 19 days with the temperature lowered to approximately 34.3 degrees Fahrenheit and yet it remained viable and showed on deleterious effects after the lower thigh was amputated. Even that portion of the thigh which was below the tourniquet, approximately 3 inches, and which was refrigerated for 3 hours after the tourniquet was applied, showed no damaging effects from this ordeal after the tourniquet and refrigeration were removed. In several other cases of amputation under ice anesthesia, that portion of the stump below the tourniquet, varying from 3 to 6 inches, has remained viable and showed good healing power after removal of the tourniquet and refrigeration.

In a recent article Mock and Mock, Jr. describe fully the technique of refrigeration anesthesia. They give chief credit for developing refrigeration as a method of preservation of tissues and as a form of anesthesia to Dr. Frederick Allen of New York, and his co-workers, Drs. Crossman, Ruggiero, Hurley, and others who pioneered in this field. In our opinion the 2 cases cited re-emphasize the value of their contribution.

CONCLUSIONS

1. Two cases of gangrene of the lower extremity complicating fractures of the pelvis are herein reported. Thigh amputations were performed in both of these cases with recovery.

2. Injuries to the iliac and femoral vessels in the presence of fractured pelvis present exceedingly serious problems to the surgeon. These complications are not sufficiently stressed in our textbooks on fractures or in the surgical literature. A search of this literature covering some 3,108 cases revealed only 13 cases in which injuries to the external iliac or femoral vessels were mentioned. In only 3 cases was gangrene of the lower extremity listed. Only 2 of these patients were subjected to amputation, with one of these recovering. The other, a gangrenous case, not amputated, died.

3. It is evident from reading the various case reports that emergency amputations as well as other emergency operations done during the early hours of shock and hemorrhage following fractured pelvis are exceedingly dangerous and have added greatly to the mortality rate. The authors believe that, in the case of amputations, refrigeration of the gangrenous extremity will hold infection and a spreading moist gangrene in abeyance, thus giving a period of days or weeks in which to get the patient in condition to withstand the ordeal of amputation. Eventually, the amputation can be performed under refrigeration anesthesia without shock and without possible general anesthetic complications. In our experience even spinal anesthesia is not altogether devoid of shock.

4. By the refrigerating of the extremity, thereby holding the gangrenous process in abeyance in the more distal portions, time is gained for the development of a certain amount of collateral circulation. Thus, amputations which otherwise might seem necessary high in the thigh may eventually be limited to more distal portions.

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COMMINUTED FRACTURES OF THE DISTAL END OF THE RADIUS

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THE need of change in the methods of treating comminuted fractures of the distal end of the radius is evident from an evaluation of the average end-results, expressed by the patients in the all too frequent complaints "My hand is weak and stiff and sore and besides my wrist is deformed." Roentgenographic studies a year after the accident will, in a high percentage of cases, reveal a shortened radius, maltilted articular face, depressed or irregular joint surface, and a relative enlargement of the ulnar styloid.

Our clinical studies, fortunately, have demonstrated that these undesirable sequelae can be minimized by the use of protracted traction. Success calls for a prolonging of traction until consolidation is complete. While reduction with restoration of radial length is usually not too difficult to obtain, it is difficult to maintain because the intact ulnar shaft acts as a pivoting point for the contracting strong radial muscles.

The original shortening in many of these wrist fractures is due not altogether to overriding or telescoping of the many fragments but to an actual crushing of the cancellous bone. In these cases an apparent end-to-end reduction will not suffice because the articular fragment must be pulled out into its normal relationship with the ulna. Furthermore, it must be held in this extended position over a long period of time (8 to 12 weeks) awaiting not only the filling in but the aging of the cancellous bone to a degree sufficient to withstand the compressing force of the muscles.

Donald Murray and other pioneers in the adhesive traction method—Boehler, Murray Meekison, Harry Blair and other advocates of skeletal traction—have demonstrated the effectiveness of extension therapy. Early release of traction and immobilization, however, were advised by many surgeons through fear of finger, wrist, and elbow joint stiffness. Thus their procedures did not routinely reap the full benefits of traction because the extension and fixation were removed before consolidation was complete.

All the anatomic and functional benefits of a satisfactory reduction sustained through traction until consolidation is complete, without fear of joint stiffness, are now possible with a new technique. The basic principles of this procedure are reduction obtained through skeletal traction in conjunction with skeletal half-pin countertraction, and immobilization by use of two slender rods instead of a cast.

TECHNIQUE

For traction a medium 0.060 Kirschner wire is passed perpendicularly through the distal one-third of the shaft of the 2d metacarpal at an angle. Or it may be passed through the center of the 1st metacarpal. The wire is connected to a miniature holder or "U." For countertraction, two half-pins of large 0.080 wire are inserted at an

a b c

Fig. 1. a, Miss M. M., extensive comminuted fracture of the distal end of the radius. b, Excellent reduction, obtained elsewhere, with plaster cast for immobilization, c, Same patient, 2 months later. The strong radial muscles will recreate deformity if not opposed by adequate traction throughout the convalescence.

Fig. 2a.

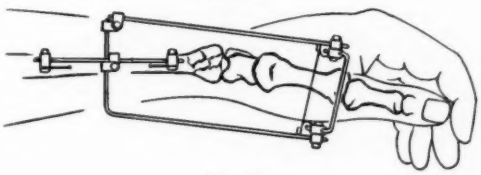


Fig. 2b.

Fig. 2. a, Illustrating the location of transfixions and means of obtaining castless immobilization. Dorsal tilting of the articular face can be controlled by immobilizing the traction force so that the 2d metacarpal remains in a straight line with the radius. The traction wire can be placed either through the 1st metacarpal, as illustrated, or through the 2d metacarpal, as illustrated in Figure 8. b, The radial half-pin fracture unit is joined to the metacarpal "U" by two small fixation rods, one straight and the other bent. This placement gives complete exposure for both lateral and anteroposterior roentgenograms. The complete unit weighs less than 3 ounces. c, The "U's" are made by bending a ⅛-inch stainless steel pin. The sides of the "U" should not be marred or scratched during the bending process. A small double clamp is slipped onto each side of the "U" before the wire is fastened into the pin clamps.

Fig. 3. Cross-section of left forearm at a level about 3 inches above the wrist joint, with transverse axis of elbow perpendicular to the floor and hand in full supination with palm perpendicular to the floor.

Fig. 4. Cross-section through the midportion of the shaft of the metacarpal of the thumb.

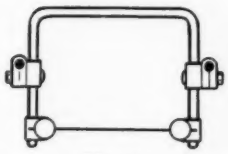


Fig. 2c.

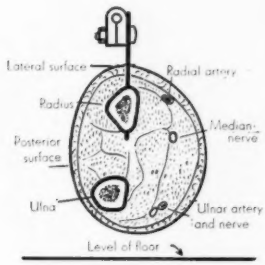


Fig. 3.

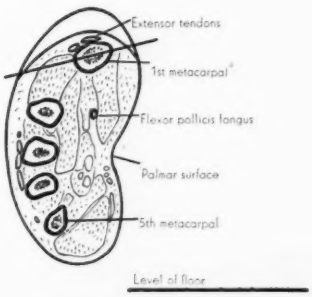
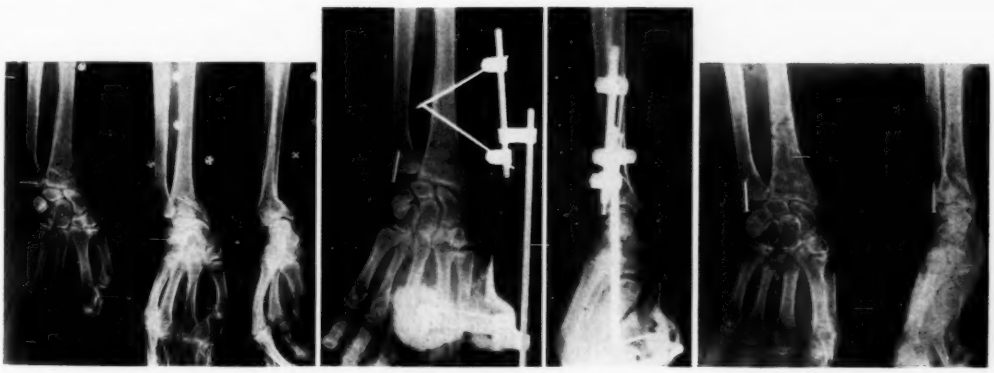


Fig. 4.



a b c

Fig. 5. a, Mrs. A. D., November 30, 1942. b, Roentgenogram on December 7, 1942, 1 week after reduction. The fracture of the ulna was held with a small brad because with her age of 80 it was thought advisable to maintain complete function not only of the fingers but also in rotation of the forearm. c, Roentgenogram, February 23, 1943, nearly 3 months after the accident. Note that the length of the radius was maintained in spite of immediate function.

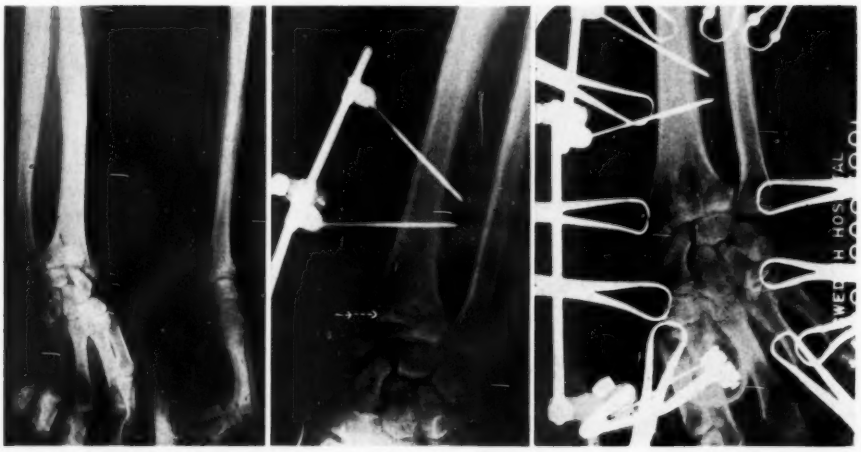


Fig. 6a. Fig. 6b. Fig. 6c.

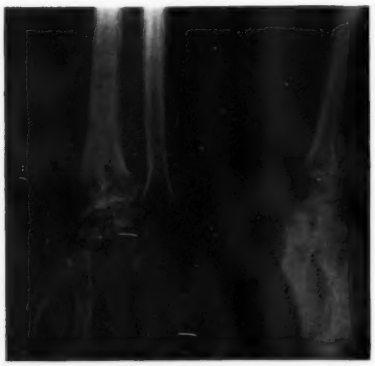


Fig. 6d.

Fig. 6. a, Mr. U. F., unusual type of comminuted fracture with superiorly displaced central articular fragment. b, While the transfixions and fixation rods maintain radial length and apposition, the small central articular fragment is still unreduced. c, This articular fragment was replaced through a dorsal incision, without disturbing the fixation rods, and the center cavity in the bone was filled in with small bone chips taken from the adjacent shaft. Roentgenogram was taken on the operating table. d, Roentgenogram 7 months later.

Fig. 7. Application of apparatus in 3 different cases. The patient in the center was unfortunate enough to have fractures of both radii into the wrist joints. With bilateral fractures such as this, the patient would be very seriously disabled if both hands were immobilized in plaster. The fracture of the left wrist was not comminuted, yet at the end of 3 months she had better function in the right than in the left hand.

angle into the lateral aspect of the radius just above the fracture site and are joined together into a half-pin fracture unit.

Manual reduction, under adequate anesthesia, is accomplished by an assistant applying countertraction to the flexed elbow as the operator pulls on the second finger or on the thumb, whichever was transfixed, and manipulates the fracture with the other hand. Two fixation rods hold the reduction. The fluoroscope serves to check on general alinement but roentgenograms should be taken for final checkup. Sufficient traction must be exerted to restore the radius to normal length. If in doubt as to the proper amount of elongation and of the tilt of the articular surface, a roentgenogram of the opposite wrist should be taken.

Immediate active function must be insisted upon. As the patient is coming out of the anesthetic, he should be instructed to start moving his

Fig. 8b.

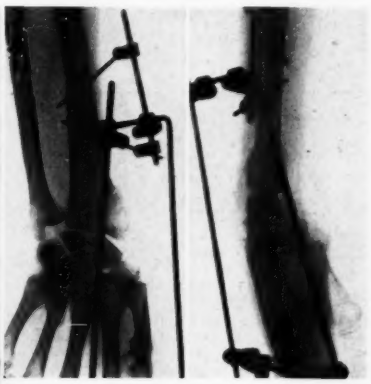


Fig. 8c.

Fig. 8. a, Cross-section through the midportion of the shaft of the 2d metacarpal and through the superior end of the proximal phalanx of the thumb. In transfixing the 2d metacarpal, its head is pressed dorsally while the heads of the 3d and 1st metacarpals are pressed volarly. The wire may be bent as it is fastened into the "U" so that the ends of the "U", when attached, will not press into the dorsum of the hand. b, Mrs. M. V., February 14, 1944, demonstrates the placement of the traction wire through the 2d metacarpal. c, Mrs. R. C., February 16, 1944, another case showing placement of the wire through the 2d metacarpal.

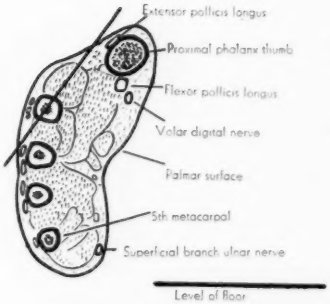


Fig. 8a.

fingers, later on grasping doorknobs, combing his hair, typing and writing, opening doors, using fork and spoon, and shaking hands. A sling should not be used unless there is a great deal of swelling, and then only for a few days. By not pampering or treating the patient as a cripple, the aggregate suffering will be held to a minimum. Immediate use of fingers and arm is the keynote to near perfect functional restoration.

An associated ulnar styloid fracture may be treated in one of the following manners: (1) ignore, since with even the firmest of plaster fixation many fractures do not unite but go on to a fibrous union and satisfactory function; (2) apply a very thin but snug plaster cast over the fixation rods, molding the plaster so as to approximate the ulnar fragments; (3) directly affix the styloid fragment by means of a metal brad through a skin puncture incision or by placing a very slender screw through a 1 inch skin incision; (4) resect and discard the distal fragment subperiosteally if early rotation of the forearm is imperative (a helpful step in preventing deformity from displacement or excess callus).

Compound fractures are routinely treated with transfixions inserted either before or after débridement; if Orr's method is elected, the plaster is preferably applied over the fracture units and fixation rods after they have been covered with sheetwadding.

Optional technique. If soft tissue injury or other fractures of the radius prohibit inserting transfixions in the radius, then a snug cast extending to the upper arm with the elbow at right angles may be used for countertraction. With such fixation roentgenograms should be taken at frequent intervals as shortening is prone to occur. If shortening does occur, the traction should be increased by forcing the metacarpal "U" further distally on the fixation rod. The fixation rods should both be of the bent type. Their superior ends are firmly fastened to the cast by means of

Fig. 9a.

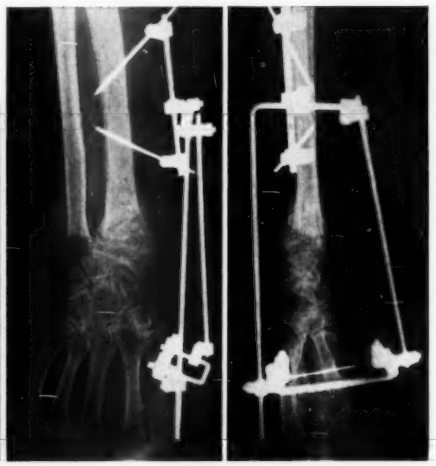


Fig. 9b.

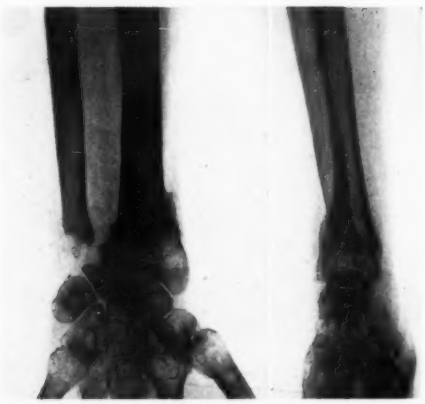


Fig. 9c.

Fig. 10d.

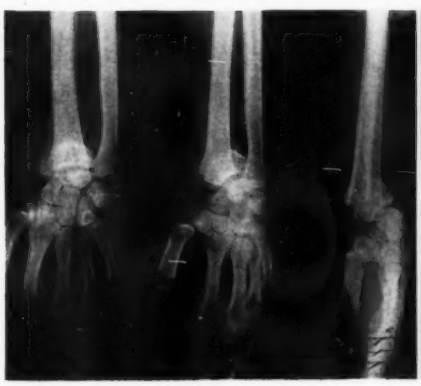


Fig. 10a.

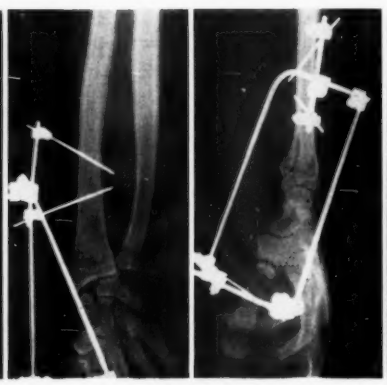


Fig. 10b.

Fig. 10c.

Fig. 11a.

Fig. 11b.

Fig. 9. Mrs. E. B., age 63. a, Roentgenograms of malunion of right radius into the wrist, taken on October 11, 1943, when patient first consulted us, 2 months after the accident. b, On October 14, 1943, the lower end of the ulna was subperiosteally resected, after which a rotation osteotomy was performed through the old fracture line in the radius. Small grafts were removed from the adjacent radial fragments and the resected portion of the ulna was cut up into many small pieces and placed between the radial fragments. These x-ray pictures were taken immediately following operation. c, Final roentgenograms taken on February 17, 1944.

Fig. 10. a, Mr. C. S., October 13, 1943, comminuted fracture of distal end of radius with marked deformity and posterior displacement. b, X-ray pictures taken after reduction the same day. c, Photograph of patient the day after reduction. d, Final roentgenogram taken December 7, 1943. Note that while there is complete length of the radial styloid there is slight shortening of the radius on the ulnar side, which may be accounted for by the fact that transfixions were removed at too early a date.

Fig. 11. Mrs. P. N., age 54. a, Roentgenogram showing very extensive comminuted fracture of an osteoporotic radius. So much comminution and loss of bone salts were noted that it was our opinion that union would be delayed for a long time or else achieved by a sacrifice in length of the radius, so 3 days after the accident we transplanted small grafts from the anterior crest of the ilium. Then the fracture was treated in the routine manner with two half-pins in the radius above and one medium size Kirschner wire through the 1st metacarpal. b, Roentgenograms on

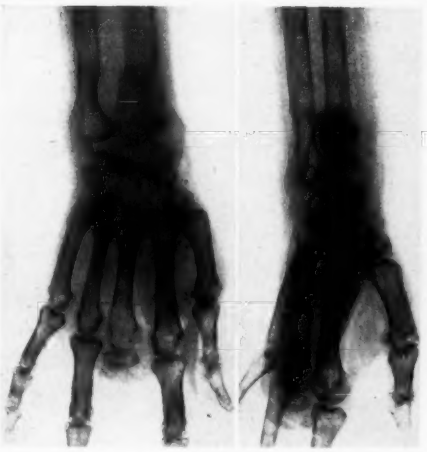


Fig. 11c.

September 3, 1943, immediately after reduction. c, Final roentgenogram on November 29, 1943. (The 3d finger amputation was the result of a previous accident and not a sequelae to transfixation.)

a plaster bandage, and the fixation rods meanwhile are kept parallel to each other and at about right angles to the "U" so as to facilitate later adjustments.

Arthrodesis of the wrist. The transfixions can be used for a contaction technique and fixation rods should then be reinforced with a light, short cast.

Malunions of wrist fractures can be successfully managed with this technique. Posterior tilting of the articular face and angulation can be corrected by means of a curved osteotomy, through a lateral incision. The enlarged and prominent end of the distal ulna is corrected by a subperiosteal resection of a sufficient amount of the lower end of the ulna and the styloid process, whether it is united or ununited. The resected bone can be cut up into small pieces and inserted between the radial fragments to fill in any space that remains after the fragments have been realined. Again, immediate and very persistent active and passive movements of the fingers will restore function during the period of callus formation and consolidation.

Period of immobilization should be much longer than the generally accepted time of about a month. Removal of traction at this time permits the muscular pull to compress the still "green"

callus with resulting radial shortening, tilting, and deformity. Traction for 2 or 3 months, as indicated by roentgenograms, is a safer period of immobilization in extensively comminuted fractures, provided the fingers and hand are actively used every hour of every day during this period.

Some will question this prolonged period of traction. With this technique, however, there is no immobilization of the metacarpophalangeal or interphalangeal joints of the thumb and fingers. Function, including rotation of the forearm, is surprisingly good during this period, and a short while after the transfixions are removed there is already a satisfactory range of motion at the wrist joint.

RÉSUMÉ

The cause of the all too frequent deformities and sequelae following comminuted fractures of the distal end of the radius is discussed. A method providing castless fixation with immediate and full function of the fingers is given in detail.

EDITORIALS

SURGERY
Gynecology and Obstetrics

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APRIL, 1944

TECHNIQUE OF VENIPUNCTURE

IN the pursuit of knowledge and achievement in various major fields of medical practice, we often neglect to learn ourselves and to teach our students the less glamorous and more practical aspects of technical therapeutics. There is no field in which this is truer than in the field of intravenous therapy and venipuncture.

Venipuncture is in general poorly performed, particularly by many students and internes. Although this can be largely corrected by systematized instruction, there have been in past years few institutions in which it has seemed of sufficient importance to warrant special attention. This may be explained by the fact that intravenous therapy in all forms has never been used as intensively as it is today. The technique of venipuncture is not generally taught to medical students or internes; therefore, it is not uncommon to see the arm of some ill patient a mass of punctures and hematomas from the unskilled attempts to get a needle into a vein. Worse than this, it is not uncommon to see multiple scars on the various extremities which are the result of having to cut down on veins. Although this was common practice in the past, I have seldom seen one who is adept at venipuncture have to resort to this procedure, even in the case of an infant. The need for instruction in venipuncture is obvious if one stops to consider the part venoclysis plays in modern medical practice. In any large general hospital the daily number of venipunctures will run into the hundreds. These might be for the administration of fluids, whole blood, plasma or other blood substitutes, for the introduction of medicaments such as the sulfonamides, penicillin, or arsenical drugs, for obtaining blood for morphologic or chemical study, for the injection of dyes for diagnosis, for the introduction of sedatives such as the barbiturates, to obtain blood from donors for refrigeration or plasma, and for the administration of anesthetics. Added to this is the outstanding importance of intravenous therapy in our armed forces, for the administration of plasma, whole blood or anesthetics, where conditions are often adverse and delay may be fatal.

In the majority of cases venipuncture may be accomplished without difficulty regardless of whether the technique is good or bad. It is liable to prove difficult, however, in cases in which veins apparently are not accessible, in cases of edema or shock, and in cases in which the patients are infants. There are many methods of performing venipuncture, and various types of equipment are used for this purpose. No one set of rules or no single type of equipment can be labeled as the right one.

Any method which produces consistently good results in all cases is satisfactory. However, to accomplish venipuncture in the cases which have just been mentioned and make it appear easy, it is necessary to practice a standard technique which is used in all cases whether the procedure is difficult or easy. If the need for intravenous therapy is urgent, as it is likely to be in military surgery, standard rules for equipment and methods must often of necessity be forgotten. Under such circumstances, the use of an antiseptic or local anesthetic may be outweighed by the urgency of instituting prompt therapy. However, minor technicalities which facilitate rapid venipuncture are even more important on the battlefield than they are in civilian practice.

The first step toward the institution of efficient venipuncture is the standardization of equipment and the training of internes and residents in the use of this equipment rather than permitting each man to use, for example, various unusual types of needles and other equipment. Standardized intravenous sets relieve the surgical supply room from maintaining a lot of unnecessary sterile equipment. Speaking in terms of economy for the institution, this standardization saves time and money and increases efficiency.

Instruction in methods to facilitate venipuncture may be as diversified as the instructor's ideas and experience. Among other things, it should include the use of a local anesthetic by infiltration prior to venipuncture. In this age when the relief of pain has become highly developed, one is not justified in hurting a patient even for the insertion of an intravenous needle if its caliber is 18 gauge or more. If a patient's veins appear to be unsatisfactory in one part of an extremity, each part of the four extremities should be examined in order to locate the most suitable veins before an attempt is made to insert a needle. Students should be instructed in the situation of all the veins accessible for intravenous therapy and anesthesia since many persons seem to feel that intravenous injection is confined to the veins in the anticubital fossa. One frequently sees an interne struggling to insert a needle into a small vein in one arm when the other arm contains veins that are entirely satisfactory for this purpose. Another common failing is to attempt venipuncture before the veins have been filled to the maximal degree. One's time is well spent beforehand in using every possible method to distend the veins as much as possible instead of wasting it by making multiple punctures over a vein that is partially collapsed. These methods include, among other things, careful adjustment of the tourniquet, massage, slapping, and other passive manipulations; and, if necessary, moist heat applied for half an hour before venipuncture is tried. A little time spent on these preliminary measures will reveal veins where none previously could be seen.

There are many types of intravenous needles. The chief points are that the needle should be sharp and that its caliber should be adequate to permit the flow of all types of fluids. Except in cases in which the patients are infants and cases in which venipuncture is exceptionally difficult, the needle should be at least 18 gauge. In surgical cases and in those in which rapid infusion is required, a 15 gauge needle is preferred. Even cold blood will run freely through a 15 gauge needle. This is of great importance in the treatment of shock and acute loss of blood on the operating table. The relation of the bevel of the needle to the size of the vein is important. Whereas it matters little whether the needle is inserted with the bevel up or down in cases in which the veins are large, if the veins are relatively small, inserting the needle with the bevel down facilitates venipuncture.

This editorial is written in the hope that it will stimulate a more standardized method of teaching the technique of venipuncture in hospitals and medical institutions and thereby render young physicians more skilled than heretofore. For the student it is just as easy to learn a procedure the right way as the wrong way. As the use of venipuncture is fundamental to the practice of medicine, instruction in this field should not be left to chance. Colleges go into great details in teaching a student the uses, actions, effects, and dangers of intravenous administration of drugs but give little thought and attention as to whether or not the student will get these drugs into the vein with the least possible difficulty.

The little time and effort expended in improving the technique of venipuncture will be repaid in many ways. As previously stated, standardization of equipment will minimize work and save time and money. Delay at the bedside is decreased when intravenous sets are complete and each one is uniform. For the physician himself, the development of skill in venipuncture under adverse conditions has its own reward. One frequently sees an ill patient who for days or weeks has received daily intravenous injections and who has justifiably become "needle-shy." Most of the large veins are thrombosed and the interne struggles valiantly if not efficiently with those that are left until he swallows his pride and calls for help. The frightened and exhausted patient looks forward in fear to the return attack and begs for just a little rest before the next onslaught. But this time the puncture is made with little pain, the needle is in the vein, the fluid running. The look of gratitude one receives from this patient leaves no doubt as to the value and importance of the service rendered. Perhaps, as some physicians have said, an extra stick or two with a needle is immaterial, but the golden rule applies to venipuncture as it does to everything else in life.

R. Charles Adams.

THE SURGEON'S LIBRARY

REVIEWS OF NEW BOOKS

THE small handbook *Physiology in Aviation*[1] by Gemmill contains the material covered in the lectures on physiology given in the School of Aviation Medicine, Naval Air Station, Pensacola, Florida. The changes in physiological functioning of the human organism exposed to decreased barometric pressures are described with exceptional clarity. This also applies to the statement of the gas laws and their application to aviation medicine. In describing the comparative volumes of gas in the intestinal tract at sea level and at various altitudes, the author inadvertently employs the table of relative gas expansion applicable to dry, rather than moist, gas. Thus, an ascent to 38,389 feet will result in one volume of gas saturated with water vapor occupying a space almost seven times that at sea level, instead of five. The physiology of respiration and circulation as affected by high altitude could hardly be presented in a more concise and illuminating fashion. The book can be highly recommended not only as an aid to students but to those who have the responsibility of teaching medicine in medical schools.

ALVAN L. BARACH.

A SHORT and excellent presentation of a relatively new specialty, aviation medicine, is made in Bauer's *Aviation Medicine*.[2] The author points out that the flight surgeon must be trained in physiology, internal medicine, ophthalmology, otology, neuropsychiatry and psychology, insofar as these specialties are concerned with flying. The physical examination of the aviator is described, with special emphasis on those defects which might handicap pilots. The pilot is not only given a thorough general physical examination but special tests are conducted on the eyes, ears, nose and throat, and equilibrium. In addition, he must pass a careful neurological and psychiatric examination. The monograph includes a brief but clear description of the strains and stresses of flying, such as the effects of high altitude, aero-embolism, high speed, cold, and wind. In the light of recent investigation, some of the conclusions concerning the physiology of high altitude may have to be modified. Thus, it has been shown that individuals may tolerate a partial pressure of oxygen of 40 millimeters of mercury in the alveolar air for a considerable period of time. The book may be highly recommended. The author is an authority on medical examination in flying personnel.

ALVAN L. BARACH.

[1] PHYSIOLOGY IN AVIATION. By Chalmers L. Gemmill, B.S., M.D. Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1943.

[2] AVIATION MEDICINE. By Louis Hopewell Bauer, M.D. Edited by Henry A. Christian. Reprinted from Oxford Loose-Leaf Medicine. New York, London, Toronto: Oxford University Press, 1943.

THE handbook of urology by Lowsley and Kirwin[3] has been brought up to date. The opening chapter explains the new blood plasma containers and illustrates their use, as well as giving a brief résumé of dosages and clinical indications.

Usual urological procedures, such as preparation for cystoscopic and pyelographic examinations, catheterization of patients, are given in detail. Likewise the common laboratory procedures used in urology are fully outlined. The names and uses of the special instruments and materials are presented and their care and maintenance emphasized. Special emphasis has been placed on sulfonamide therapy and the necessity of adequate fluid intake and periodic blood examination upon patients receiving sulfa drugs. Much of the book is devoted to the surgical aspect of urology, in an attempt to familiarize the nurse with operations and factors influencing good results. The dietary management of renal diseases is included together with sample diets.

The careful perusal of this text by nurses handling urological patients will relieve the busy urologist of the time consuming duty of explaining various procedures and orders. Also the book is a ready reference for the urologist himself, who at times needs to explain technical procedures in terms the average layman can understand. This book should be found in the library of all nursing and medical institutions.

JAMES I. FARRELL.

IT is always of interest to compare textbooks of surgery issued during a period of war with those that appeared during previous wars. While the volume *Textbook of Surgical Treatment*[4] by Illingworth and his collaborators is in no sense a war manual, it does serve to illustrate beautifully the surgical principles practiced at the present time. When compared with similar works published during World War I, it acts as an excellent medium of distinction between the types of surgery practiced now and those done a generation ago. In doing so it offers tangible evidence that the improvement in mortality and morbidity rates that are now becoming so apparent among casualties as well as in civilian surgery is not due simply to the use of blood plasma, sulfonamides and penicillin as many would have us believe but is primarily the result of better trained surgeons who possess a better knowledge of the fundamental principles that form the bases of good surgical care.

[3] UROLOGY FOR NURSES. By Oswald S. Lowsley, M.D., and Thomas J. Kirwin, M.D., Philadelphia: J. P. Lippincott Co., 1943.

[4] TEXTBOOK OF SURGICAL TREATMENT; INCLUDING OPERATIVE SURGERY. Edited by C. F. W. Illingworth, M.D., Ch.M., F.R.C.S.E. Baltimore: The Williams & Wilkins Co., 1943.

The authors chiefly represent the schools of Glasgow, Edinburgh, and Aberdeen, and the volume reflects the sanity and progressiveness that one has long since learned to expect from these institutions. In slightly over 500 pages an effort has been made by the author and his contributors to cover the entire field of surgery including not only the ordinary surgical techniques but their indications as based on underlying physiologic principles as well. Most subjects have thus been treated briefly and while for the most part this has been done clearly it lends a certain rigidity to the consideration. As an example may be offered the relatively lengthy treatment of the two-stage operation for carcinoma of the rectum with bare mention of the one-stage abdominoperineal procedure of Miles.

Greater attention has wisely been given to those surgical operations that are more commonly used. The student is thus not confused by obsolete techniques or numerous modifications of a simple technique. This reviewer would prefer to have seen more space devoted to the chemistry of electrolyte balance and to nitrogen metabolism. The preoperative preparation for surgery of gastric and large bowel carcinoma could likewise be extended. The preference for sulfapyridine over other sulfonamides in surgical practice may also be questioned as well as the preference of the rectal route for the parenteral administration of physiologic salt solution. But such criticisms as these are minor and probably represent an individual opinion. They do not detract materially from the general excellence of the book. This volume will be found invaluable to the young surgeon and of considerable use to the expert.

NATHAN WOMACK.

THE routine use of the slit lamp in examination of the eye is now recognized as necessary. *Biomicroscopy of the Eye*[1] by Berliner makes available an atlas of over 500 illustrations including 40 pages of vivid color plates. There is a comprehensive discussion of the changes which may be found in the lid margins, conjunctiva, cornea, and anterior chamber with the slit lamp. A second volume due in 1945 will include iris, lens, and vitreous. The seven hundred pages are printed on good paper in print large enough to read easily and comprise an up to date interesting account of many of the unusual as well as the usual conditions of the eye. Bibliography and index are appended. The development of the slit lamp including the various instruments and technique of its use are described. The chapter by Sugar on the gonioscope and anterior chamber angle is a valuable addition.

The superb *Atlas* by Vogt (2 volumes, 1930) because of the German text and high price has not been as widely used as this new volume by Berliner should be. The Von der Heydt English translation of the 1921 Vogt *Atlas* came at an earlier day when the slit lamp was not as widely used as now. There are also less extensive books by Butler (1927), Meesman (1927 German), and Koby (1930). Berliner may be recommended as the best large text which is easily available on the subject.

GAIL R. SOPER.

THE author of *Clinical Diagnosis by Laboratory Examinations*[2] has accomplished an enormous task and has produced a far more comprehensive and complete work on the subject than has been published up to this time. Dr. Kolmer has divided the text into three parts: I. The Clinical Interpretation of Laboratory Examinations; II. The Practical Applications of Laboratory Examinations in Clinical Diagnosis; and III. Technic of Laboratory Examinations. In part I, the subject is discussed from the viewpoint of the examination concerned somewhat more than one-half the book being devoted to this subject. Part II is concerned with the laboratory findings observed in diseases which are grouped in systems. Part III consists of a somewhat limited, but still adequate presentation of laboratory technique which occupies about 130 pages.

The work is well conceived and executed and really stands alone in its field at the present time. In view of its size, it is not surprising that there have crept into the text some statements that appear to be erroneous. Thus on page 11, the life of the transfused red cell is said to be 12 to 13 days, while on page 486 it is placed at 3 to 4 months. On page 120 the paragraph about the van den Bergh reaction seems confused. The use of prothrombin determinations in liver function tests is omitted. The author follows general custom in urging the addition of paraaminobenzoic acid to culture media though there is some evidence that the necessity for this addition has been overemphasized. There is a good deal of confusion in respect to compatibility tests in reference to the Rh factor. The author's statement is that the Rh agglutinin "agglutinates corpuscles only at low temperatures," although Levine recommends that such compatibilities be carried out at 37 degrees C. As a matter of fact, it should be recognized that a compatibility test is not a reliable protection against transfusion reactions due to the Rh factor. On page 611 it is stated that the "A.Z." test may be positive 5 to 14 days after the first missed menstrual period, while on page 614 the time is given as 5 to 14 days after conception. The author does not discuss the use of cover slips in making blood films. He recommends the use of potassium oxalate as anticoagulant in hematocrit determinations when it seems to be generally agreed that Heller and Paul's mixture of potassium and ammonium oxalate is superior for this purpose. In common with most authorities, the author gives the sedimentation rate normally from 0 to 8 or 10 millimeters per hour. There is grave doubt whether a proper rate in normal blood can be zero. Such a result is so frequently the effect of im-

[1] BIOMICROSCOPY OF THE EYE; SLIT LAMP MICROSCOPY OF THE LIVING EYE. By M. L. Berliner, M.D. Vol. 1. New York and London: Paul B. Hoeber, Inc., 1943.

[2] CLINICAL DIAGNOSIS BY LABORATORY EXAMINATIONS. By John A. Kolmer, M.S., M.D., Dr. P.H., Sc.D., LL.D., F.A.C.P. New York and London: D. Appleton-Century Co., 1943.

proper collection of the sample, that a doubt should always be raised when this result is obtained.

However, these are admittedly minor criticisms and should not be regarded as in any way detracting from the value of the work as a whole. The discussion of the interpretation of bacteriological examinations should be read by every physician and the comments on the leucocyte count in appendicitis also deserve special mention. The book can be recommended unreservedly to physicians in every branch of medicine.

It is a large book of 1,239 pages whose size could have been reduced somewhat by a judicious use of small type, and the omission of textual repetition of some of the many excellent tables.

RALPH G. STILLMAN.

THE book *Peripheral Vascular Diseases (Angiology)*,[1] by Saul S. Samuels, is one of the Oxford Medical Outline Series designed, to use the author's own words, "with the purpose that it will stimulate further interest in every phase of peripheral vascular diseases" among students and graduate physicians. This little book is based essentially on the second edition of the author's *The Diagnosis and Treatment of Diseases of the Peripheral Arteries*, published in 1940. There is added an excellent outline of the anatomy of the blood vessels and of the autonomic nervous system of the extremities as well as an outline on varicose veins, thrombophlebitis, and diseases of the lymphatics of the extremities. Each chapter is followed by a well selected bibliography.

The outlines on thromboangiitis obliterans and arteriosclerosis obliterans are quite complete with respect to etiology, diagnosis, and treatment. The author states categorically that lumbar sympathectomy is not indicated in thromboangiitis obliterans. While he recognizes that sympathectomy is futile in arteriosclerosis obliterans because of the absence of vasospasm in the great majority of cases, he does not base his objection to this procedure in Buerger's disease on this premise, but merely states that sympathectomy does not forestall any of the complications of this disease. In this opinion, he is at variance with many workers in this field who advise sympathectomy in those cases of Buerger's disease in which vasospasm can be demonstrated by spinal anesthesia and nerve block. It should be said, however, that Dr. Samuels has had a very wide experience in this field. His opinion, therefore, should be very seriously considered.

The reviewer should have desired to see a more adequate outline on varicose veins and thrombophlebitis. While these conditions are not nearly as serious in their implications as are Buerger's disease and arteriosclerosis obliterans, the confusion concerning their proper classification and treatment is almost as great. A more detailed outline of the disturbed hemodynamics in varicose veins and of the treatment of both this condition and of thrombophlebitis in the light of the author's extensive experience would have greatly enhanced the value of this portion of the book.

On the whole, the book attains the purpose of the author admirably. It can be heartily recommended as a synopsis of the subject of peripheral vascular diseases.

J. T. GAULT.

THE author of the excellent work *Proctology*[2] has succeeded in condensing an unusually large amount of essential and valuable information into a readily serviceable outline form. Every other page is blank, thus affording the reader ample space in which to incorporate references, sketches, and pertinent notes.

Although the author has purposely omitted discussion of "controversial points," the reviewer believes that many rectal surgeons will take issue with the statement that ether, as an anesthetic agent, provides complete muscular relaxation. With regard to the anal sphincter mechanism complete relaxation can be obtained with ether only when the deep third plane of anesthesia is reached, with concomitant encroachment on the margin of safety. In the reviewer's opinion anal sphincter relaxation can be established more easily and with greater safety by means of regional block anesthesia, i.e. spinal or sacral.

The author lists both the advantages and the disadvantages of ether, but for caudal and for spinal anesthesia he states only their disadvantages. He is right in saying that caudal anesthesia fails in 20 per cent of cases, but he fails to add that sacral anesthesia, which can be established during the "waiting period" of the caudal portion of this procedure, will reduce the failures almost to zero, provided the anesthetic agent is properly placed.

The reviewer is particularly pleased to find a very practical presentation of the problems of congenital malformations. When the surgeon is suddenly confronted with the urgent need for this information, he wants it quickly—and here it is.

The presentation of the major surgical subjects is excellent indeed, especially in view of the limitations of outline form. For this work the author recommends either general or spinal anesthesia. In view of the importance of colonic and major rectal surgery, and because of the great advantage of teamwork of anesthetist and surgeon, the reviewer believes that it would have been well to mention the invaluable contribution of continuous spinal anesthesia supplemented as necessary by the intravenous administration of sodium pentothal.

With regard to the surgical treatment of pilonidal cyst, the author's method of complete excision followed by packing the open wound is satisfactory, for the most part, in civilian practice. In military surgery, however, this method results in far too many

[1] PERIPHERAL VASCULAR DISEASES (ANGIOLOGY). By Saul S. Samuels, A.M., M.D. Oxford Medical Outline Series. London, New York, Toronto: Oxford University Press, 1943.

[2] PROCTOLOGY. By Sylvan D. Manheim, M.D. Oxford Medical Outline Series. London, New York, and Toronto: Oxford University Press, 1943.

sick days. Until we learn how to accomplish successful primary closure, the reviewer feels that "compromise" procedures are worth trying. One such method is the "exteriorization" operation as described by Buie.

Students and general practitioners should find this book a valuable guide and a stimulus to further study. J. PEERMAN NESSELRODD.

THE same pattern which has been so successfully used in previous years is followed in *The 1943 Year Book of Radiology*.[1] This text again serves as a handy and rapid reference source for one interested in radiology.

The usual high standard for the reproduction of films has been maintained. And in spite of the war there is practically no diminution in the size of this book. R. G. WILLY.

THE reviewer read *The Education of Nurses*[2] by Isabel Maitland Stewart with great benefit and interest. A more descriptive title would be "The Education of Educators of Nurses" for the "book is designed primarily for professional students and workers in the field of nursing education." It is the latest in a series of Macmillan nursing education monographs and intended as a general introduction to the other volumes of the series which take up specifically and in more detail the various activities and problems involved in nursing education. A very commendable special purpose of the book is "to provide a general orientation for non-nursing groups who are becoming increasingly interested in this branch of education and aware of their responsibilities in relation to it. Such groups include board members and administrative officers in hospitals, nursing service agencies, higher educational institutions; members of state and other accrediting bodies; interested individuals in the allied professions of medicine, public health, and education; parents and friends of student and graduate nurses; responsible government officials and public-spirited citizens."

The historical foundations and trends and the reasons therefor are developed chronologically in eight chapters. Each chapter is devoted to a special period of years, arbitrarily chosen because of their particular significance in the development of nursing education. The presentation is clear and concise, well documented, and at the end of each chapter are appended a number of appropriate provocative questions. GEORGE H. COLEMAN.

DESIGNED as a laboratory guide for undergraduate students in a course in experimental surgery, the purpose of McCaughan's *Experimental Surgery*[3] is not to teach surgical technique but to emphasize fundamental surgical principles by laboratory experimentation. This method has been of incalculable value in the undergraduate teaching of physiology and pharmacology but has not been employed to any great extent in the teaching of surgery. Complete instructions are provided for conducting a class in experimental surgery together with simple methods for performing operations under aseptic conditions and a series of thirteen exercises chosen to demonstrate various surgical problems. At the close of each chapter there are a bibliography of important papers and a list of questions admirably designed to bring out the important features of the subjects under discussion. LESTER R. DRAGSTEDT.

THE tables included in *White Blood Cell Differential Tables*[4] by Waugh are very useful in deriving rapidly the figures necessary for the construction of the hemogram, a further development of technical hematology, in which the total count of each type of white blood cell is computed from the usual total white blood cell count and the formula of differential percentages. Such a hemogram affords a more comprehensive visualization and understanding of the whole blood picture and should have a much wider usage by clinicians. GEORGE H. COLEMAN.

[1] THE 1943 YEAR BOOK OF RADIOLOGY. DIAGNOSIS edited by Charles A. Waters, M.D., and Whitmer B. Firor, M.D. THERAPEUTICS, edited by Ira I. Kaplan, B.Bc., M.D. Chicago: The Year Book Publishers, Inc., 1943.

[2] THE EDUCATION OF NURSES; HISTORICAL FOUNDATIONS AND MODERN TRENDS. By Isabel Maitland Stewart, R.N., A.M. New York: The Macmillan Company, 1943.

[3] EXPERIMENTAL SURGERY; A LABORATORY GUIDE FOR UNDERGRADUATE STUDENTS. By J. M. McCaughan, B.S., M.D., Ph.D. St. Louis: The C. V. Mosby Co., 1943.

[4] WHITE BLOOD CELL DIFFERENTIAL TABLES. By Theodore R. Waugh, B.A., M.D., C.M. New York and London: D. Appleton-Century Co., Inc., 1943.